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(72) Feltaláló(k):
FELDMANN, Michael, 82349 Kailling-Pentenried (DE)

(73) Jogosult(ak):
Meissner, Jan A., 8700 Küsnacht-ZH (CH)

(74) Képviselő:
Danubia Szabadalmi és Jogi Iroda Kft.,
Budapest

(54) **Biogáz üzem, valamint eljárás biogáz előállítására lignintartalmú megújuló nyersanyagokból**

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Biogas Plant and Process for the Production of Biogas from Ligneous Renewable resources

Description

[0001] The present invention concerns a biogas plant, specifically a biomass power plant for the production of biogas according to the generic portion of claim 1, and a process for the production of biogas from straw.

[0002] In biogas plants, straw is virtually never used as a fermentation substrate at present; it is used only indirectly in biogas plants in small amounts as litter contained in solid manure. Specifically, for reasons which will be explained in the following, there is a technical bias against the use of straw as a fermentation substrate.

[0003] Over 3,500 wet fermentation plants are currently in operation in Germany, as opposed to only about 20 plants for the solid fermentation (dry fermentation) of renewable raw materials. In wet fermentation plants, the use of straw is out of the question because the wet fermentation material must be circulated with paddle wheels or propellers, and the straw would become wound around the paddles or propellers in this process. For this reason, straw-containing solid manure is hardly ever used in wet fermentation plants; rather, liquid manure is primarily preferred. If the straw is chopped in order to circumvent this mechanical problem, the chopped straw floats and therefore does not mix with the wet fermentation substrate. Moreover, in this process, it generally plugs the outlets or overflows of the wet fermenter. For these reasons, the use of straw as a fermentation substrate for wet fermentation plants is currently out of the question.

[0004] Existing biomass power plants or biogas plants for the production of biogas according to the solid fermentation process are typically small agricultural plants with two to six fermenters. According to the only recently published Final Report "Monitoring of the Effect of the Revised Renewable Energy Act (REA) on the Development of Electricity Generation from Biomass," which was commissioned by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMU), dry fermentation has not yet reached a marketable level. In this report, the plants currently in operation are seen more as demonstration plants (see pg. 52, Figs. 5-2 of said Final Report). In principle, it would be possible to use straw as a fermentation substrate in such solid fermentation plants. However, this is not done at present, because it is commonly assumed that the gas yield of straw is too low.

[0005] Conventionally, known solid fermentation processes primarily use organic wastes, solid cattle and pig manure, and dried chicken manure instead of straw. The other main materials used are slightly lignified renewable raw materials such as e.g. freshly harvested grass, grass silage, grain whole plant silage and corn whole plant silage, as well as hay, potatoes and beet chips.

[0006] As the currently known biogas plants using solid fermentation are typically in rural areas, such as on farms, and only have a relatively low throughput, the need for fermentation is usually met from the farmer's own inventory and possibly that of neighboring farms. For solid fermentation plants that are larger than conventional ones, however, the procurement of suitable fermentation substrates in sufficient amounts and under economical conditions constitutes a problem.

[0007] EP 0286100 A describes anaerobic fermentation in which highly heterogeneous raw waste is used as input material, consisting for example of lignocelluose-containing substances such as paper and cardboard, but also including non-biodegradable substances such as plastics (films, bags, knives, forks, etc.), metal objects (knives, forks, batteries, windshield wiper motors, aluminum foils, etc.), wood, ceramics and glass. However, use of straw as a fermentation substrate is not mentioned.

[0008] DE4308920 A1 describes a device for the improved pre-treatment of organic wastes, in particular for the improved hydrolysis of biodegradable organic waste fractions in order to substantially reduce the volume and mass of organic substances. The purpose of using devices for waste treatment is not optimization of the biogas or methane yield, but reduction of the volume of waste to be deposited. In this case as well, use of the fermentation substrate straw is not mentioned.

[0009] US2006/0275895 A1 describes a biogas plant operating according to the process of wet fermentation which essentially consists of a chopper, a mixing tank upstream from the fermentation reactor, a fermentation reactor, a first separator, a second separator and a downstream hydrolysis unit. All typical fermentation substrates, such as organic waste, sewage sludge, corn, grass, unprocessed straw, grain plant silage, corn silage, hay and agricultural fertilizers (feces, urine, liquid manure, straw-containing solid manure) are used as input materials.

[0010] WO2004/016797 A1 describes a process and a plant for the production of biogas from organic material. This essentially comprises a standard or grain mill (or optionally, only a simple mill for the crushing of biomass pellets), a mixing tank with an agitator, a fermentation reactor with an agitator, pumps and a control unit. Any kind of biomass, as well as slaughterhouse waste and liquid manure, may be used as input material. Without going into the various specific characteristics of the input materials, biomass as used in this application is understood to refer to all plants which use the natural process of photosynthesis to produce plant mass, such as silage, straw, grain, chaff, rapeseed, sugar beets, turnips, corn, sunflowers, cabbage, potatoes, molasses, peas, beans, lentils, flax, lupine, pasture plants such as alfalfa, grass and clover, lawn clippings, roadside greenery, hay and tree leaves. Liquid manure and slaughterhouse waste can also be used as co-substrates.

[0011] The present invention is based on the ideas of a biogas plant, in particular a biomass power plant, and a process for the production of biogas, which solve the problem of procuring and processing suitable fermentation substrates in sufficient amounts, in particular for larger plants operating on an industrial scale, under economical conditions.

[0012] These ideas are achieved by means of the biogas plant having the characteristics of claim 1 and by means of the process having the characteristics of claim 22. Advantageous improvements are given in the dependent claims.

[0013] According to the invention, the biogas plant is provided with devices for the mechanical and thermal comminution and optionally for the chemical comminution of straw. Contrary to the commonly-held view, comminution of straw in this plant can also be achieved with a considerable gas yield. This makes biogas production, in particular biogas production by the solid fermentation process, accessible for a new class of renewable raw materials, as straw is available in large amounts and is inexpensive. Straw can be used as a supplement to conventional fresh mass such as silage from plant clippings, silage from whole grain plants, etc., and can thus supply even numerous large and very large biomass power plants, with for example 20 or more fermenters and a respective electrical output of over 5,000 kW, under economical conditions.

[0014] Preferably, the device for the thermal comminution of straw comprises a device for saturated steam treatment. The device for saturated steam treatment preferably comprises a pressure container and means which are suitable for producing steam in the pressure container at a pressure of 20 to 30 bar and a temperature of 180°C to 250°C. Saturated steam treatment takes place at the described pressures and temperatures and typically lasts 5 to 15 minutes. The function of the saturated steam treatment will be described using wheat straw as an example.

[0015] Wheat straw is composed of approximately 40% cellulose, 23% arabinoxylan (hemicellulose), and 21% lignin, with all three main components having a densely-packed structure. The major obstacle to the biochemical utilization of cellulose and hemicellulose is lignin, which is indigestible for microbes and blocks the path of bacteria to cellulose and hemicellulose. In saturated steam treatment, the lignin structures are macerated or melted, but they are not separated to any essential degree from the stalks due to the relatively short duration of treatment. After saturated steam treatment, the lignin again solidifies. On solidification of the lignin, however, loose droplet-like structures form, leaving sufficient spaces through which first aqueous organic acids and then bacteria can reach the cellulose and arabinoxylan, breaking them down by means of the known four-step fermentation process.

[0016] Therefore, in the saturated steam treatment described here, the lignin is primarily altered in its microscopic structure, but not separated by dissolution from the straw stalks. In particular, the structure of the straw stalks as such remains intact. This differs from thermal pressure hydrolysis, which is carried out under basically similar conditions, but for longer periods, and in which true hydrolysis takes place, i.e. dissolution of previously solid or dry substances in water. In thermal pressure hydrolysis, the structure of the straw stalks is broken down, resulting in a syrup-like suspension.

[0017] In an advantageous improvement, the device for the comminution of straw comprises a container for the soaking thereof for saturated steam treatment, for example in water. When the soaked straw is subjected to saturated steam treatment, the absorbed water evaporates suddenly, causing the lignocellulose structures to be ruptured and making the cellulose more readily accessibly to the bacteria.

[0018] In an advantageous embodiment, a device for the mechanical comminution of straw is provided by means of which the straw can be mechanically broken down prior to the saturated steam treatment, for example by chopping. This further contributes toward separation of the lignin structures and facilitates subsequent fermentation.

[0019] According to the invention, in addition to the thermal breakdown, which is preferably carried out by saturated steam treatment, the straw is also mechanically comminuted by grinding, preferably in a hammer mill. This form of comminution mechanically destroys the lignin structures. However, grinding alone is not expedient in use of the solid fermentation process, because a pasty pulp would form which would clog the fermentation mass and prevent percolation.

[0020] In this disclosure, the straw may be present in bale form, which in particular highly facilitates the transport and handling thereof, as described in greater detail below. As the structure of e.g. straw stalks remains intact during saturated steam treatment, straw bales also retain their form during saturated steam treatment and can be simply and easily transported after such treatment. Moreover, a particular advantage of bales is that they can be layered into the bottom of a garage-type fermenter, causing the filling level of the fermenter to rise. In general, the filling level of the fermenter is limited because from a certain level of the substrate in the fermenter on, the pressure at the bottom thereof becomes so high that the substrate is too strongly condensed to allow percolate to seep through. Straw bale layers, however, which are inserted at the bottom of a fermenter, are far more pressure-stable than conventional fermentation substrate. Even at high pressure, the straw bale layer remains permeable to percolate, so that the usual filling level in the fermenter can be increased up to the straw bale layer. The fermenters can therefore be constructed higher than usual at the level of the straw bale layer, thus keeping fermenter-specific technical costs (doors, gas technology, sensors, valves and openings, percolate nozzles, outlets, piping, pumps, etc.) constant and increasing the efficiency of the biogas plant as a whole.

[0021] In order to increase the efficiency of a softening phase and/or saturated steam treatment of straw bales, means for perforation of the bales may be provided. These means for perforation are suitable for perforating a bale from two sides in such a manner that the holes created by perforation of one side and those created by perforation of the other side are separated by material bridges. This type of perforation of the bale makes both soaking of the bale and subsequent saturated steam treatment more efficient.

[0022] The device for saturated steam treatment may have at least one spike on which a straw bale can be placed, with the spike having an inner cavity into which steam can be supplied and comprising a plurality of openings through which the steam can exit the cavity. In this manner, the hot, high-pressure steam used during the saturated steam treatment can be fed through the spike into the bale, thus allowing the saturated steam atmosphere to reach the material inside the bale as well to a sufficient degree. In a simpler version, in which the saturated steam atmosphere is fed into the pressure container in an obvious manner, the problem may occur that the air present in the bale is compressed in an inner section of the bale, but does not thoroughly mix with the steam rapidly enough, causing the saturated steam treatment to be carried out less effectively in this inner section of the bale.

[0023] If loose straw is used, a steam-permeable container for the storage thereof is preferably provided in the pressure container. Moreover, means for transporting the steam-permeable container into and out of the pressure container, such as rails or a roller conveyer, are preferably provided.

[0024] In a particularly advantageous improvement of the plant according to the invention, the pressure container has an upper opening through which it can be charged with loose straw and a lower opening through which the loose straw can fall out of the steam-permeable container. As explained in further detail below by means of an exemplary embodiment, such a configuration makes it possible to carry out saturated steam treatment on a "virtually continuous" basis, with the loose straw being added batchwise to the container and the pressure container then being closed for saturated steam treatment, after which the treated loose material is dropped from the container through the lower opening, and a subsequent batch is finally dropped through the upper opening into the container.

[0025] In an advantageous improvement, the device for saturated steam treatment can comprise a plurality of pressure containers which are connected to one another by conduits. In this manner, a plurality of pressure containers can be supplied by a single steam source, for example a single steam reservoir, which markedly increases efficiency, particularly in larger power plants.

[0026] In an advantageous improvement, the device for the comminution of straw comprises a container for the soaking thereof in a water-lye solution, a water-acid solution, percolate, or liquid manure. This soaking constitutes an example of the aforementioned chemical comminution. In particular, this soaking can be carried out after the saturated steam treatment. This soaking causes (weakly aerobic) pre-hydrolysis to be initiated which takes place before introduction into the fermenter. For this purpose, the soaked straw is preferably heated to 30 to 50°C after soaking and before introduction into the fermenter. This heating can be combined with transporting of the straw from the comminution device to the fermenter, as described in further detail below. This pre-hydrolysis causes the subsequent anaerobic bacterial fermentation in the fermenter to be further accelerated.

[0027] It should be noted that the structure of the biogas plant and the process for the production of biogas by means of the comminution process described here do not require that additional yeasts, fungi or enzymes be added. Indeed, only the ligneous material is subjected to autohydrolysis and bacterial hydrolysis. The use of bacteria instead of yeasts, fungi or enzymes is considerably more economical, because the chemical and biochemical processes take place more rapidly in bacterial hydrolysis than in enzymatic hydrolysis. In addition, this allows a considerable reduction in the cost of obtaining and handling enzymes and/or acids compared to methods requiring external input thereof.

[0028] An important improvement of the invention lies in the manner in which the additional process step of straw comminution is integrated into the operation of the biogas plant. The device for the comminution of straw is economically advantageous, particularly if the throughput of the plant or the biomass power plant is high. On the contrary, however, currently known biomass power plants for solid fermentation are usually very small and limited to rural areas. They are equipped with two to six smaller fermenters and reach an effective electrical output of only 100 to 700 kW. This is attributable on the one hand to the fact that dry fermentation is generally considered as not yet market-ready, but also to the graduated minimum remuneration of the REA for energy input from renewable resource plants, which decreases by up to 15% when the limit of 500 kW is exceeded. Other factors speaking against the installation of larger biogas plants using dry fermentation are that the required supply of fermentation substrate must be insured for years in advance according to financing requirements and that the operators, typically farmers, wish to rely on renewable raw materials that they can produce themselves.

[0029] However, by means of the biogas plant according to the invention and the process according to the invention, which allow the use of straw, the supply of fermentation substrate can also be ensured for much larger plants, for example because much larger amounts of straw are generated in crop farming than are currently required, and because it can also be transported in a relatively economical manner over longer distances using corresponding (large-scale) technology. On the other hand, the investment and operating costs for a device for comminution of straw are all the more advantageous the greater the throughput of the biogas plant is. There is a content-based connection between the possibility of comminution of straw and the size of the biogas plant in that the device for comminution of straw plays an essential role in ensuring the supply of larger biogas plants as well with fermentation substrate, and on the other hand, it is the size of the biogas plant and the use of inexpensive substrate-type straw which make investment in the device for comminution in particular and the large biomass power plant as a whole economical.

[0030] With a previously unknown size of biogas plants having for example 15 to 30 large garage-type fermenters, operation of the biogas plant, and in particular transporting the fermentation substrate and the digestate, must be efficiently carried out. A further object is to integrate the above-described comminution of straw into the operational process of the biogas plant.

[0031] In an advantageous improvement, the devices for the comminution of straw are accommodated in a delivery and loading area of the biogas plant. The delivery and loading area preferably comprises stationary conveyance technology, which is suitable for conveying fresh mass from the delivery and loading area to a fermenter forecourt, from where a plurality of garage-type fermenters can be accessed. While the fresh mass and the digestate are transported using a wheel loader in conventional biogas plants, according to this improvement, stationary conveyance technology is provided, by means of which even large amounts of fresh mass can efficiently be transported to the fermenter forecourt in order to be fed from there into the fermenters. This stationary conveyance technology also makes it possible to enclose the entire biogas plant, allowing emission of odors into the environment to be prevented and making it possible to operate the biogas plant near residential areas as well.

[0032] When the biogas plant is completely enclosed, to a certain extent, the delivery and loading area constitutes an interface between the enclosed inner area and the outer area, and is therefore arranged in an outer section of the plant. In contrast, for logistical reasons, the fermenter forecourt is arranged centrally in the plant. The stationary conveyance technology allows the fresh mass or the fermentation substrate to be brought from the delivery and loading area to the fermenter forecourt without requiring the use of transport vehicles, which would emit exhaust inside the enclosure area and would also increase operating costs. Preferably, the delivery and loading area is under slight negative pressure, so that even during delivery of fresh mass and loading of digestate, only a little air penetrates to the outside, thus minimizing emission of odors into the environment.

[0033] Preferably, there is at least one enclosed delivery bunker for fresh mass in the delivery and loading area. Moreover, first conveying means are preferably provided which are suitable for conveying fresh mass from at least one delivery bunker for fresh mass to a fresh mass bunker. These first conveying means may for example comprise screw conveyors, elevators and conveyor belts on which the fresh mass is conveyed to the fresh mass bunker from the various delivery bunkers. This has the advantage that the fresh mass is already thoroughly mixed, because it is conveyed from various delivery bunkers onto one and the same pile, so subsequent thorough mixing of the fresh mass is either unnecessary or does not have to be conducted so intensively. This described fresh mass is composed not only of the straw to be comminuted, but also of additional fresh mass such as that used in previously known biogas plants using solid fermentation.

[0034] Moreover, the delivery and loading area preferably comprises a second conveying means, in particular a pusher blade, which is suitable for conveying fresh mass towards the fermenter forecourt . In this case, the fresh mass bunker has a double function: on the one hand, it serves as a transportation route from the delivery area to the fermenter forecourt, and on the other, it serves as an interim storage unit for fresh mass. It is important that the fresh mass first brought into the fresh mass bunker is also the first to leave said bunker. This means that the fresh mass delivered to the fermenter forecourt is always roughly of the same age and therefore pre-hydrolyzed to the same degree. This provides uniform substrate consistency, which is advantageous for the subsequent fermentation.

[0035] In an advantageous improvement, the delivery and loading area also comprises an unloading site for straw, particularly for straw in bale form. At the unloading site, a crane is preferably provided that is suitable for gripping and conveying bale material.

[0036] Moreover, as mentioned above, the devices for comminution of straw are provided in the delivery and loading area, which is of one of the types described above.

[0037] Preferably, third conveying means, in particular roller conveyers or shuffle conveyors, are also provided, which are suitable for conveying individual bales or packages of bales along a bale channel to the fermenter forecourt.

[0038] In the disclosure, a distinction is also made between loose fresh material and bale material. The bale material is also transported by the third conveying means and the bale channel in a highly efficient manner from the periphery to the fermenter forecourt, which makes it possible to achieve high throughput at very low operating cost. Preferably, a converter is arranged at the end of the bale channel near the fermenter forecourt, which is suitable for removing packages of bales from the bale channel and transferring them to a wheel loader or fork-lift truck as a package. As explained in further detail below by means of an exemplary embodiment, a layer of bale material should preferably be inserted at the bottom of each fermenter. This can be carried out in a particularly efficient and rapid manner if already suitable packages of bales, for example packages of eight bales, can be transferred to the wheel loader or fork-lift truck and then offloaded into the fermenter as is.

[0039] Preferably, the delivery bunker, fresh mass bunker and/or bale channel can be heated, and preferably by means of waste heat produced by one or a plurality of gas engines. Preheating of the fresh mass compensates for temperature losses from the old material occurring during refreshing of the fermentation material. This accelerates reuse of the biogas formed after refreshing of the fermentation material. Moreover, this also makes it possible to carry out the above-described weakly aerobic pre-hydrolysis, which reduces the time required for complete fermentation of the fermentation mass and increases plant efficiency (substrate throughput) and thus profitability.

[0040] In an advantageous improvement, a digestate bunker is provided which can be accessed from the fermenter forecourt for the introduction of digestate. The digestate bunker preferably contains stationary conveying means which are suitable for transporting digestate through the digestate bunker. In an advantageous improvement, these stationary conveying means are screw conveyors which are arranged at the ends of the digestate bunker. The digestate bunker is preferably dimensioned in such a manner that it can hold at least a two-day amount of the digestate expected to be produced.

[0041] The digestate bunker according to the aforementioned improvement of the invention has a threefold function. First, it serves as an interim storage unit for digestate, and second, it provides a transporting device for digestate from the central fermenter forecourt to the periphery. The digestate bunker is of sufficient size to provide interim storage of the digestate for at least two days, so that it does not have to be picked up on the weekends, when truck driving is restricted. Finally, post-fermentation takes place in the digestate bunker as a third function, and it is therefore connected to the biogas system.

In this manner, additional biogas is obtained from the digestate which would be lost if a simpler design were used.

[0042] A bulk trough for digestate is preferably arranged at the inlet end of the digestate bunker. In this manner, the digestates can be poured directly from the fermenter forecourt into the bulk trough; they are then automatically transported to the periphery.

[0043] Preferably, a device for dehydration of the digestate is provided at the outlet end of the gestate bunker. The digestate contains nutrient and bacteria-rich percolate which can be supplied via a ring line to the percolate circulation tanks described below if needed. If such percolate is required, it is pressed from the digestate in the dehydration device and supplied via the ring line to the percolate circulation tanks. Otherwise, the dehydration device can be dispensed with and the wetter digestate transported off as is.

[0044] Additionally or alternatively, a drying system for the drying of digestate may be provided which preferably uses the waste heat of a gas spark-ignition engine for drying the digestate. Moreover, a gasification system is preferably provided which is suitable for producing wood gas or lean gas from dried digestate according to the wood gasification method, in particular based on carbonization or pyrolysis. This lean gas can then be added to the biogas produced by fermentation. The subsequent gasification of the digestate makes it possible to produce roughly another 20% of the volume of biogas as wood/lean gas, thus substantially increasing the efficiency of the raw material in producing gas. In particular, there is a technical connection between the use of straw with predigestion and subsequent wood gasification. On the one hand, gasification of the digestate makes it possible to increase the gas yield if this should turn out to be less than the biologically possible yield due to incomplete comminution of the straw. In addition, ligneous substances, as the name indicates, are particularly suitable for wood gasification. In this manner, the use of straw as a fermentation substrate and the subsequent wood gasification of digestate complement each other in an ideal manner.

[0045] While the above improvements of the invention refer to plants for solid fermentation, the invention is not limited thereto.

[0046] According to the invention, the straw is broken down by both thermal comminution and mechanical grinding, causing the lignin structures to be broken down as well. For example, investigations by the inventor have indicated that contrary to the widespread view in expert circles, if ground straw were fed into a wet fermentation plant, this would give rise to a considerable increase in gas yield. Specifically, the flat lignin structures are also destroyed by this grinding. The cellulose and arabinoxylan can then be dissolved by the aqueous organic acids contained in the fermentation mass, which are also contained in the liquid manure typically present in wet fermentation plants, and to an even greater extent in pure wet renewable resource plants, which operate without liquid manure. This provides the anaerobic methane-producing bacteria with access to biomass previously considered unsuitable.

[0047] In a preferred embodiment of the invention, chemical comminution of the straw in biogas plants for solid fermentation may also be carried out. In this case, the straw is mixed with another fresh material, preferably solid manure, days before being placed in the fermenter. The urea present in the solid manure can then in turn begin to separate the lignin and make the cellulose and arabinoxylan available for hydrolysis. It is important here that additional or separately provided ligneous renewable resources are chemically broken down by the urea contained in the solid manure. In this case, mixing of the loose straw with the solid manure would typically be carried out some time before being placed in the fermenter, with a period of a few days being preferred. In a very simple embodiment of the invention, layers of solid manure and layers of straw can be alternately piled up in the fermenter without requiring any advance period, and layers of other, not highly lignified renewable raw materials can also be optionally included. This allows the urea from the upper solid manure layer to penetrate together with the percolate into the straw layer and at least partly separate the flat lignin structures. It is also possible to mix loose straw with the digestate, and optionally other renewable raw materials. In this case, the acidic percolate at least partly breaks down the flat lignin structures and causes the material to generate biogas, although not with the yield obtainable using the other above-described comminution processes, in particular saturated steam treatment.

[0048] Preferably, the inoculation material coming into the fermenter together with the fresh mass is thoroughly milled and pressed out before mixing by means of a mechanical press such as a screw press, allowing the material to be mechanically broken down at least to some extent and optionally providing access to bound nutrients for anaerobic bacterial fermentation. The screw press can be configured so as to be mobile, for example arranged on a low loader so that it can be driven from the fermenter forecourt to the respective fermenter.

[0049] In an advantageous embodiment, a device for thermal pressure hydrolysis is provided for thermal breakdown by means of which the material can be subjected to thermal pressure hydrolysis either before or after going through the solid fermentation plant, but before removal of the digestate. Thermal pressure hydrolysis takes place under conditions similar to those of the above-described saturated steam treatment, but for a longer duration, for example 60 to 120 minutes. In thermal pressure hydrolysis, the lignin is completely separated so that a syrup-like suspension is formed. Moreover, true hydrolysis takes place, which means the splitting up of polymers into monomers as a result of the physical influence of water and heat. The syrup-like suspension can then be (re)fed into the fermentation process or sold to companies which manufacture second-generation fuels from this material. In this case, the lignin content is also utilized, as well as additional unutilized organic matter. This is not possible in anaerobic bacterial fermentation.

[0050] In order to provide better understanding of the present invention, in the following we will refer to an exemplary embodiment presented in the drawings, which will be described using specialized terminology. However, it should be noted that this does not limit the scope of the invention, as such changes and further modifications of the biogas plant and the process shown, as well as further applications of the invention disclosed in said drawings, are considered to be part of the ordinary current or future knowledge of the person skilled in the art. The figures show exemplary embodiments of the invention, specifically:

Fig. 1 an elevation of a biomass power plant according to an improvement of the invention seen from the west,

Fig. 2 an elevation of the biomass power plant of Fig. 1 seen from the north,

Fig. 3 an elevation of the biomass power plant of Fig. 1 seen from the south,

Fig. 4 an elevation of the biomass power plant of Fig. 1 seen from the east,

Fig. 5 a cross-sectional view of the biomass power plant of Fig. 1 seen from the west,

Fig. 6 a plan view of the ground floor of the biomass power plant of Fig. 1,

Fig. 7 an enlarged section of the plan view of Fig. 6 which shows an electricity and heat production system;

Fig. 8 an enlarged section of the plan view of Fig. 6 which shows a delivery and loading area,

Fig. 9 a plan view of the upper floors of the biomass power plant of Fig. 1,

Fig. 10 a schematic diagram of two views of a perforated straw bale,

Fig. 11 a schematic cross-sectional view of a device for saturated steam treatment,

Fig. 12 a schematic cross-sectional view of another device for saturated steam treatment intended for loose ligneous material,

Fig. 13 a schematic cross-sectional view of a device for saturated steam treatment intended for saturated steam treatment of material in bale form,

Fig. 14 a schematic cross-sectional view of a device for saturated steam treatment comprising a plurality of pressure containers.

[0051] In the following, a biomass power plant (BMPP) 10 is described in detail as an exemplary embodiment of a biogas plant according to an improvement of the invention. Figs. 1 to 4 show four external views of the BMPP 10, and Fig. 5 shows a cross-section thereof. Fig. 6 shows a plan view of the ground floor of the BMPP 10. Fig. 7 shows an enlarged partial section of the elevation of Fig. 10 in which an electricity and heat production system of the BMPP is shown. Fig. 8 shows another partial section of the elevation of Fig. 6 in which a delivery and loading area is shown in an enlarged view. Fig. 9 shows a plan view of the upper floor of the BMPP 10.

[0052] With reference to the plan view of Fig. 6, the BMPP 10 is divided into a basic section 12 and an expansion section 14. The basic section 12 comprises 18 garage-type fermenters which are arranged in two rows, with a northern and southern row being shown in the view of Fig. 5. Between the two rows of fermenters 16 is a fermenter forecourt 18 onto which the doors 20 of the fermenters 16 open. It should be noted that for the sake of clarity, not all of the fermenters 16 and fermenter doors 20 are indicated by reference nos. in the figures.

[0053] Moreover, the basic section 12 comprises an electricity and heat production system 22 shown in enlarged view in Fig. 7 and described in greater detail below. The basic section 12 also comprises a delivery and loading area 24 shown in enlarged view in Fig. 8 and also described in further detail below.

[0054] As can be seen in Figs. 1 to 6, the entire basic section 12 is enclosed by a hall structure which in particular includes a fermenter forecourt (FF) hall section 26 and a delivery and loading area hall section 28, as can be clearly seen in particular in Figs. 1, 4 and 5. The entire hall construction or enclosure of the basic sections 12 is ventilated by means of a large central exhaust system, so that there is always slight negative pressure inside the hall construction with respect to atmospheric pressure.

[0055] The expansion section 14 essentially comprises 11 additional fermenters 16' and an extension of the FF hall sections 26. The expansion section 14 is used to provide up to 11 additional fermenters 16' when needed. This means that the BMPP 10 is first built without the expansion section 14 and put into operation. During operation, it is then determined whether the available 18 fermenters 16 of the basic sections 12 produce enough biogas to supply the four gas engines (not shown), which are intended for the BMPP 10, with gas under full load. If this is not the case, the corresponding number of fermenters 16' can be added in the expansion section 14, which may therefore be smaller than shown in Fig. 6. In other words, the BMPP 10 has a modular configuration, which is advantageous for achieving an optimal final configuration, because the exact biogas yield depends on multiple factors, including the consistency of the fresh mass available, and cannot be theoretically predicted with precision.

[0056] The northern and southern fermenter rows are connected by a technical bridge 30 which can be seen in particular in Figs. 5, 6 and 9. The technical bridge 30 spans the FF 18 at a level which makes it possible for wheel loaders, two of which are shown by way of example in Fig. 5, to drive under it even with their loading shovels fully extended without being able to touch and damage the technical bridge.

[0057] With reference to Fig. 9, the upper floor of the BMPP 10 comprises three film gas storage units 32 in the basic section 12 and two further film gas storage units 32' in the expansion section 14. The film gas storage units 32 can be clearly seen in the cross-sectional views of Figs. 5 and 15. They take up the biogas produced by the fermenters 16 or 16' in a manner described in further detail below.

[0058] Moreover, the upper floor comprises five percolate circulation tanks (PCT) 34 in the basic section 12 and four PCTs 34' in the expansion section 14, which can also be clearly seen in the cross-sectional views of Fig. 5. Each PCT 34 is arranged above three fermenters 16 and receives percolate from them, which is collected at the bottom of the fermenters and pumped into the PCT 34. The term "percolate" refers to the liquid component of the fermentation material, which is similar to liquid fertilizer.

[0059] Moreover, the upper floor has an exhaust cooling area 31, a southern technical area 36 and a northern technical area 38 which are connected to one another by the technical bridge 30. Moreover, roof lights 40 are arranged in the FF hall section 26 and in the delivery and loading area hall section 28.

[0060] Now that we have provided a rough overview of the components of the BMPP 10, the individual sections and components and their mode of operation will be described in detail below.

1. Fermenter forecourt

[0061] The fermenter forecourt (FF) 18 is arranged in the center of the BMPP 10. It serves as a transportation route for fresh mass to the respective fermenters 16, 16' or for digestate substance from the fermenters 16, 16'. In addition, it serves as a mixing surface on which the contents of a fermenter are spread, after which roughly a fifth to a fourth is removed as percolate, and to compensate for this removal and for the weight loss due to gasification, roughly a third is supplemented with fresh mass and mixed with the old fermentation mass. This work can be carried out on the FF 18 of a large wheel loader, as schematically shown in Fig. 5. In the middle of the FF 18, there is a drainage channel provided with a grating into which the silage effluent and released percolate flow. At the level of the technical bridge 30, the drainage channel has a collecting chute (not shown) via which the liquid produced is transported through a percolate ring line (not shown) to one of the PCTs 34.

2. Delivery and loading area

[0062] The delivery and loading area 24 is shown in Fig. 8 in an enlarged plan view. In the exemplary embodiment shown, with respect to delivery, a distinction is made between loose fresh mass and structural fresh mass or fresh bale material. In the embodiment shown, four delivery bunkers 42 for the loose fresh mass are provided, which are enclosed by the delivery and loading area hall section 28. A truck can back into the enclosed delivery bunker and dump or push off the fresh mass load in the delivery bunkers 42. As there is slight negative pressure throughout the delivery and loading area 24, virtually no noxious odors escape from the enclosure. Each delivery bunker 42 has a floor that is tapered conically downward and is provided at its lowest point with one or a plurality of double screw conveyors (not shown) which transport the fresh mass horizontally to a cup elevator (not shown), which transports the fresh mass onto a conveyor belt 44 or directly to a conveyor belt in a lower position.

[0063] From the conveyor belt 44, the fresh mass is dropped into a fresh mass bunker 46. As the fresh mass is conveyed in four or more different bunkers on the same conveyor belt 44 and dumped onto the same pile in the fresh mass bunker 46, the fresh mass is automatically thoroughly mixed.

[0064] The fresh mass bunker 46 is an elongated room that connects the delivery and loading area 24 with the fermenter forecourt 18, as can be seen in particular in Fig. 6. The fresh mass bunker 46 has a floor heater by means of which the fresh mass is already heated to a temperature of 42°C, so that the fermentation mass inside a fermenter 16, 16', which is supplemented by the fresh mass, is not cooled by said fermenter, so that the fermentation process restarts quickly after closure of the fermenter 16 and/or weakly aerobic pre-hydrolysis can already take place, which reduces fermentation time and increases both the efficiency (throughput of fermentation substrate) and profitability of the plant.

[0065] The fresh mass bunker 46 has a double function. On the one hand, it serves as an interim or buffer storage unit for loose fresh mass. On the other hand, it serves as a transportation route between the delivery and loading area 24, i.e. the periphery of the BMPP 10, and the centrally located fermenter forecourt 18. For transportation, a pusher blade or slider (not shown) is arranged in the fresh mass bunker 46 which slides fresh mass newly added from above towards the fermenter forecourt 18. The slider is then returned to its starting position in order to make room for new fresh mass. This sliding mechanism makes it possible to push the fresh mass out of the fresh mass bunker 46 on the side of the fermenter forecourt 18 as well, roughly in the same order in which it was inserted at the inlet into the fresh bunker. This means that the fresh mass which reaches the fermenter forecourt 18 is always roughly of the same age and therefore of a constant consistency, which is advantageous for subsequent fermentation.

[0066] Moreover, the delivery and loading area 24 comprises a section for the delivery and transport of structural or bale material, in particular for straw. This section for the delivery and transport of bale material comprises a supply area 48, a bale delivery area 50, a comminution area 52 and an interim storage unit 54. In the following, this section of the delivery and loading areas 24 is described with reference to straw as a highly lignified structural material in bale form, but it is to be understood that this section can also be used for the delivery, processing and further transport of other structural material in bale form.

[0067] A crane (not shown) is arranged on a rail in such a manner that it can pick up and set down bales in each of the rooms 48 to 54. The straw bales are delivered to the straw delivery room 50 and transported by the crane (not shown) to the interim storage unit 54. Before the straw is conveyed to the fermenter forecourt 18, it is pretreated in the comminution area 52, i.e. comminuted. Comminution of the straw is necessary because it is highly lignified and the bacteria in the fermenter 16 can only reach the nutrients enclosed in lignin with great difficulty because of the lignin-encrusted cellulose. In the comminution area 52, the straw may be comminuted in different ways depending on the configuration of the BMPP 10. For example, the straw can be chemically broken down by soaking it in a container of water, a water-lye solution or a water-acid solution. This soaking partially dissolves the lignin, which was largely enclosed by the cellulose. After removal from the container, the cellulose is no longer hidden behind a lignin crust, but is accessible for hydrolysis and the bacteria. This converts the straw, which has been used in the past in conventional wet or dry fermentation systems only as a structural material, into a valuable fermentation substrate which plays an essential role in biogas production.

[0068] In an alternative embodiment, the straw can be broken down in the comminution area 52, but also in another manner, for example mechanically using a hammer mill or by being exposed to thermal pressure, i.e. heated at a high pressure of e.g. 20 to 30 bar for five to ten minutes at 180°C to 250°C. This breaks down the lignin. After cooling of the straw, the lignin solidifies again, but in the form of very small beads with spaces in between, which opens a pathway for the autohydrolytic organic acids and the anaerobic bacteria to the nutrients in the straw. A further exemplary embodiment is an extension of thermal pressure treatment in which the pressure in the corresponding container is suddenly reduced, causing the water in the straw structures to evaporate and expand very rapidly. This causes the lignin structures to be destroyed and exposes the nutrients to the anaerobic bacteria. The further details of straw comminution are given in the following section.

[0069] In the supply area 48, a roller conveyer 56 is provided on which the individual straw bales and/or packages of straw bales are placed by the crane (not shown), and which conveys the straw bales through a bale channel 58, which is arranged parallel to the fresh mass bunker 46, to the fermenter forecourt 18 (see Fig. 6).

[0070] As can be seen from the above description, both the loose fresh mass and the fresh mass in bale form are transported by stationary conveyance technology from the delivery and loading area 24 to the fermenter forecourt 18. Specifically, the fresh mass bunker 46 and the bale channel 58 constitute the connection between the central fermenter forecourt 18 and the peripheral delivery and loading area 24, and this transport takes place completely in the enclosed BMPP 10. Transport using stationary conveyance technology is suitable for high throughputs, and in particular is faster, saves more space, and is more economical than delivery with wheel loaders. As can be seen from Fig. 6, the bale channel 58 and the fresh mass bunker 46 end at a central location in the fermenter forecourt 18, so that the paths between the end of the fresh mass bunker 46 or the bale channel 58 on the fermenter forecourt side and the fermenter 16 to be supplied are generally short.

[0071] As mentioned above, comminution of the straw in the comminution area 52 makes it possible to use straw as a substrate despite its high lignin content. This is highly advantageous, because straw is generated in grain production in any event, and there is insufficient use for this. As the BMPP 10 is designed for renewable raw materials, it is advisable to specifically plant raw materials suitable for use in the BMPP 10 around said BMPP 10, with said raw materials generally not being intended for consumption, however. On the other hand, this constitutes a certain conflict of objectives, because a certain proportion of the limited areas available is always reserved for food production. The use of straw as a fermentation substrate constitutes a highly attractive solution, as straw is generated in grain production anyway, which allows the simultaneous production of food products and biomass suitable for power plants.

[0072] However, straw offers another advantage. In general, the filling level in fermenters is limited by the pressure produced at bottom of the fermenter: this pressure must always be so low that the fermentation substrate is still permeable to percolate. In contrast, when a layer of straw bales is added in the lowest layer of each fermenter 16 according to an improvement of the invention, the entire usual filling level of fermentation material can be placed on this layer, as the straw bale layer is still permeable to percolate at the pressure which then occurs. This lowest straw layer therefore constitutes an additional amount of fermentation substrate which can be used in a fermenter so that the plant efficiency (space utilization measured in new substrate per fermenter and day) is markedly increased.

[0073] In an advantageous improvement of the invention, the straw bales are placed in packages of eight straw bales on the roller conveyers 56, which are two bales wide and four bales high. These packages are transported as a whole through the bale channel 58, picked up at the end thereof in the fermenter forecourt 18 by a converter (not shown) and transferred to a wheel loader or fork-lift truck which also receives the packages as a whole or in 2 parts and brings them to the fermenter. The aforementioned lower straw bale layer can be relatively easily and quickly built up from these packages.

[0074] As can further be seen in Fig. 8, a digestate bunker 60 is provided which extends parallel to the fresh mass bunker between the fermenter forecourt 18 and the delivery and loading area 24. At the end facing the fermenter forecourt, the digestate bunker 60 has a bulk trough 62 for digestate which forms the inlet to the digestate bunker 60. Digestates are dumped into this bulk trough 62 by a wheel loader. From there, they are pressed by means of a screw conveyor into the digestate bunker. By discontinuously adding new digestate constantly, the mass is slowly transported through the digestate bunker 60 to the other end, where it is then transported to the digestate bunker 60 by means of further screw conveyors.

[0075] The digestate bunker 60 has a threefold function. On the one hand, it serves as a transportation route between the fermenter forecourt 18 in the center of the BMPP 10 and the delivery and loading area, with similar advantages to those described with respect to the fresh mass bunker 46 and the bale channel 58. On the other hand, however, the digestate bunker 60 also serves as a thermophilically operated secondary fermenter and operates virtually as an additional fermenter. For this reason, the digestate bunker 60 is also connected to the biogas system.

[0076] Finally, the digestate bunker 60 serves as an interim storage unit for digestate. It is dimensioned in such a way that it can hold at least as much digestate as can be produced in two days. This makes it possible to transport off the produced digestate on weekdays, so that this transportation is not hindered by truck driving restrictions.

[0077] A switch 64 is provided at the outlet end of the digestate bunkers 60 which makes it possible to transport the digestate either directly via a conveyor belt 66 to loading silos 68 or to take a detour via a dehydration device 70. In the exemplary embodiment shown, the dehydration device 70 is a screw press which is suitable for pressing water or percolate from the digestate and feeding it to one of the PCTs 34. Whether the detour via the dehydration device 70 is taken depends on the current need for percolate.

[0078] The loading silos for digestate 68 are tower silos which are arranged on A-frames so that a truck can drive under the silos 68 and can thus be easily loaded.

[0079] In an alternative embodiment, a conventional drying system, for example a drum or band dryer (not shown), is provided which is suitable for drying the digestate to a water content of less than 25%, and preferably 15%. The heat for the drying system is preferably provided by the waste heat of the generator sets. Moreover, a gasification system (not shown) is provided in which the dried digestate is subjected to the process referred to as wood gasification, in which flammable wood gas (lean gas) is obtained from the dried digestate by pyrolysis or partial combustion under reduced air. After removal of the tar produced from the wood gas according to any known process, this wood gas or lean gas is fed into the biogas system and can then be used without any problems as fuel for the gas spark-ignition engines.

[0080] The energy content of the wood gas reduces the requirement for biogas by up to 20%, or even more, so that for the same power output, up to 20% or even 30% less substrate is needed for fermentation. This causes a considerable increase in the profitability of the plant as a whole.

3. Straw comminution

[0081] As mentioned above, in the biomass power plant shown, the straw is delivered in the delivery and loading area 24 and comminuted in the comminution area 52 and optionally in the supply area 48 as well. In this embodiment of the invention, straw is delivered in bale form and comminuted in bale form as well, and then finally brought in bale form into the garage-type fermenters 16. The bales should preferably have a density of over 200 kg/m^3, which can only be obtained using maximum-pressure bale presses. The advantage of such a high straw bale density is that the capacity of a truck is utilized to an optimal degree, with respect both to the allowable weight of the load and the possible volume thereof, so that the straw can be delivered under economical conditions even over long distances.

[0082] In the embodiment shown here, pre-treatment for the comminution of straw comprises four steps which are carried out in the comminution area 52 or the supply area 48, specifically

1.) perforating or punching of the straw bales,

2.) soaking of the straw bales in water,

3.) saturated steam treatment of the macerated straw bales, and

4.) soaking of the straw bales in percolate.

[0083] These steps and the devices used therein are described in the following.

[0084] In parallel, a portion of the straw can be comminuted by "grinding" and/or "thermal pressure hydrolysis." A combination of the different form of comminution is particularly preferred, as each has its advantages and drawbacks for practical operation. The best overall effect is achieved by means of a combination.

[0085] According to the invention, a step of the grinding the straw to a powdery consistency is provided in which the ground straw can be mixed into the remaining fresh mass. The ground straw provides a particularly high gas yield, but the amount with respect to the fresh mass is limited in that the pulverized straw moistened by the percolate forms a sticky mass which must be mixed with sufficient fresh mass for handling reasons.

[0086] Preferably, between 5% and 25% by weight of the fermentation substrate as a whole is composed of ground straw. Preferably, between 5% and 35% of the entire straw used is ground and thus mechanically broken down.

[0087] Moreover, independently of pre-treatment of the remaining straw, 5-20% of the total straw used should be comminuted by thermal pressure hydrolysis, and the syrup-like material thus obtained, referred to as the "slurry," should be fed into the percolate cycle.

[0088] Finally, independently of the other process steps for breaking down the straw, the fermentation substrate removed from the fermenter should preferably be mechanically pressed through.

3.1. Perforation

[0089] Perforation of the straw is conducted in order to make the inside of the straw bale accessible for soaking, saturated steam treatment and for subsequent soaking in percolate. In the embodiment described here, the straw bales are perforated from two sides, as will be described in further detail with reference to Fig. 10.

[0090] The upper portion of Fig. 10 shows a perspective view of a straw bale 72 looking at the underside 74 thereof. The lower figure shows a perspective view of the straw bale 72 looking at the upper side 76 thereof. From the underside 74, the straw bale 72 is first perforated by a first set of holes 78 which do not pass through the entire straw bale 72. Moreover, from the upper side 76, the straw bale 72 is perforated by a second set of holes 80 which also do not pass through the entire straw bale 72. The holes 78 and 80 are staggered relative to one another in such a manner that the holes of the first set 78 and the holes of the second set 80 are separated from one another by material bridges. By means of this type of perforation, the soaking water of the second step, the saturated steam of the third step and the percolate of the fourth step can properly penetrate the inside of the straw bale 72 without running out on the other side.

3.2. Soaking

[0091] In the comminution area 52 of Fig. 8, containers suitable for the soaking of straw bales are provided which are not shown in the figure. The sizes of the containers for soaking are adjusted to fit the sizes of the straw bales so that soaking can be conducted in a space-saving and efficiently manner.

3.3. Saturated steam treatment

[0092] In the comminution area 52 or in the supply area 48, a device for saturated steam treatment is provided. With reference to Figs. 11 to 14, various devices for saturated steam treatment are described which can be used in the plant shown or a modified plant.

[0093] Fig. 11 shows a schematic cross-sectional view of a simple configuration of a device 82 for saturated steam treatment. The device 82 comprises a pressure container 84 with a lid 83, which is articulated via a hinge 85 that pivots around the pressure container 84. A supply device for the straw is schematically indicated and identified with reference no. 87. If the device 82 for saturated steam treatment is to be used for treating straw bales, the transporting means 87 may consist for example of a conveyor belt or a roller conveyor. If the device 82 for loose straw 106 is to be used, the transporting means 87 may consist of rails on which a container 89 for loose material in the pressure container 84 can be slid. The container 89 is steam-permeable, but suitable for storing the loose material, and may for example be a grid container or basket open at the top. The lid 83 of the pressure container 84 may be closed by a closing mechanism 91. Preferably, the lid 83 for opening the pressure container 84 pivots inward, as can be seen for example in Fig. 14, so that the lid 83 is pressed into a closed position by the pressure inside the pressure container 84 and therefore more easily sealed.

[0094] The pressure container 84 is connected to a supply line 93 and a supply valve 95 through which the saturated steam 102 can be supplied at a pressure of up to 30 bar and a temperature of up to 250°C from a steam reservoir (not shown) to the pressure container 84. Moreover, the pressure container 84 is connected to an outlet line 97 with an outlet valve 98 through which the steam can be discharged from the pressure container 84 after the saturated steam treatment. Moreover, a compressor 100 is arranged in the outlet line 97 through which the saturated steam 102 can be conveyed back to the reservoir (not shown).

[0095] In the following, the process of saturated steam treatment is explained with reference to the device 82 for saturated steam treatment of Fig. 11. First, the straw 106 is placed in the form of bales or loose material in a container such as the container 89 in the pressure container 84, and the pressure container 84 is closed. After this, the valve 95 in the supply line 93 is opened so that hot steam at a temperature of 180°C to 250°C and a high pressure of between 20 and 30 bar is introduced from a steam reservoir (not shown) into the pressure container 84. The introduced saturated steam is shown schematically in Fig. 11 with the reference no. 102.

[0096] The straw 106 is exposed to the saturated steam 102 for 5 to 15 minutes. This causes the lignin in the material to be melted but not separated from the material. For the efficiency of saturated steam treatment, it is preferably to presoak the straw in the aforementioned second step, because the water is then already present in the material and only needs to be heated, which shortens the duration of treatment.

[0097] After the preset residence time of 5 to 15 minutes, the saturated steam is released from the pressure container 84 through the outlet line 97. This release of pressure preferably occurs suddenly, so that the pressure drops by at least 80% within 5 seconds or less. The rapid reduction in pressure suddenly evaporates the water in the structures of the straw, which therefore quickly expands. This tears the lignin structures of the straw apart, making the nutrients (cellulose and arabinoxylan) accessible to aqueous organic acids and anaerobic bacteria.

[0098] After the release of the pressure from the pressure container 84, the straw 106 is removed from the pressure container 84 and cools off. On cooing, the molten lignin resolidifies. However, on solidification of the lignin, the original flat structures do not reform; rather, it coagulates into a droplet structure, leaving spaces through which first the organic acids and then bacteria can reach the cellulose and the arabinoxylan (hemicellulose).

[0099] The basic configuration of the device 82 for saturated steam treatment shown in Fig. 11 can be modified in various ways, and a few examples of such modifications are given in the following. Identical or functionally identical components having the same reference nos. are as shown in Fig. 11, and their description is not repeated.

[0100] Fig. 12 shows a configuration of a device for saturated steam treatment which is designed for virtually continuous processing of loose material. In this case as well, a container 89 for loose material 106 is provided inside the pressure container 84, but it is firmly installed in the pressure container 84. In order to fill the container 89, a pressure-tight slider 108 is opened so that the ligneous material 106 falls through a funnel 110 into the container 88. When a sufficient amount of material 106 is in the container 89, the pressure-tight slider 108 is closed, and saturated steam treatment takes place in the same manner as described with reference to Fig. 11. In addition to the components of Fig. 11, however, Fig. 12 shows a reservoir 112 for saturated steam 102 which is equipped with a heater 114. Following saturated steam treatment, the steam is released through the outlet line 97 and conveyed by pressure via the compressor 100 into the reservoir 112. After this, an additional pressure-tight slider 108 is opened at the lower end of the container, and the comminuted loose material 106 falls onto a conveyor belt 116 to be transported further.

[0101] At the lower end of the container 84, particularly in thermal pressure hydrolysis, a liquid mass 117 collects which is referred to as a "slurry" and is discharged through a further line 118 and fed through a line 120 into the percolate circulation tanks (not shown).

[0102] Fig. 13 shows a further embodiment 122 of a device for saturated steam treatment which is specially configured for the treatment of bale material, in particular straw bales 72. The configuration is essentially similar to the configuration of Fig. 11, and will not be described again. However, the essential difference is that a spike or mandrel 124 is provided which has an inner cavity 126 and nozzle-like openings 128 connected to this inner cavity 126. The inner cavity 126 is in fluid connection with the supply line 93.

[0103] In operation of the device for saturated steam treatment 122 of Fig. 13, a straw bale 72 or 106, via the transporting means 87, which in the embodiment shown comprise a roller conveyer, inserted from the right in the view of Fig. 13 into the pressure container 84 and placed on the spike 124. The pressure container 84 is then closed as usual, and the saturated steam 102 is injected via the supply line

93, the inner cavity 126 of the spike 124, and the nozzle-like openings 128 into the straw bale 72. This allows the inside of the straw bale 72 as well to effectively come into contact with the saturated steam. Specifically, as shown in Fig. 11, if the saturated steam is fed into the material from the outside only, it can happen, particularly in the case of a highly compressed bale, that the saturated steam does not come into sufficiently contact with the material inside the bale. Instead, the air is compressed inside the bale by the highly pressurized steam, possibly without being thoroughly mixed with the hot steam because of the relatively short treatment time. The use of the spike 124 ensures that thorough saturated steam treatment is conducted inside the bale 72 as well.

[0104] Finally, Fig. 14 shows a further device 130 for saturated steam treatment which comprises five pressure containers 84 that are provided with spikes 124 similarly to device 122 of Fig. 13. In the device 130 of Fig. 14, however, the pressure containers 84 are vertically arranged so that the straw bales can be fed from above with a crane 132 into the pressure containers 84. The crane 132 comprises a trolley 134 and a frame 136 on which are configured an upper gripper 138 for an upper bale and a lower gripper 140 for a lower bale. Thus the crane 130 can grip two straw bales 72 arranged vertically on top of each other, insert them into the pressure container 84 and place them on a spike 124, which for this purpose is roughly twice as long as the spike 124 of Fig. 13.

[0105] All of the pressure containers 84 of Fig. 14 are connected to the same pressure reservoir 112 by a conduit. In this case, similarly to Fig. 13, the saturated steam 102 is fed in each time via the supply line 92 using the spike 124 and pressed through the straw bales 72 into the pressure container 84.

[0106] The improvement of Fig. 14 is designed for plant with a high throughput in which the saturated steam treatment can be carried out with high efficiency.

3.4 Soaking in percolate or the like

[0107] In the fourth aforementioned process step, the pretreated bales are soaked in percolate which constitutes a weakly acidic solution. Alternatively, however, the bales can also be soaked in a weakly alkaline solution such as a sodium hydroxide solution. After soaking, the bales are heated to roughly 40°C, which can be carried out for example by heating the straw channel 46 (see Fig. 8) using waste heat from the gas spark-ignition engine. Soaking of the material after saturated steam treatment and before anaerobic bacterial fermentation initiates weakly aerobic pre-hydrolysis, which further accelerates subsequent fermentation by anaerobic bacteria. In soaking with percolate, the anaerobic bacteria are directly at the site of the fresh material, which is also advantageous.

[0108] It is important to note that by means of the process for the comminution of straw described here, the material in the fermenter provides a considerable gas yield with moderate residence times and without requiring that additional enzymes, fungi or yeasts be added. The naturally present acid content of the straw (roughly 3 to 4%) therefore also dissolves the solid cellulose and converts it into an aqueous solution (autohydrolysis). The biogenic polymers are chemically broken down by the action of the organic acid and/or biochemically split by the action of bacteria into lower-molecular compounds (monosaccharides, amino acids, short-chain peptides, long-chain fatty acids, glycerol). These compounds are present in water-soluble form at the end of the phase. However this takes place without requiring enzymes, bacteria or yeasts to be added first. The ligneous material in this embodiment is subjected only to autohydrolysis and bacterial hydrolysis.

[0109] The comminution described here in detail with the aforementioned four process steps is highly effective and advantageous, but it is not absolutely necessary for all four steps to be used, and simpler processes having fewer or only a selection of steps, but still allowing fermentation of straw, can also be carried out.

[0110] With respect to the preferred chemical comminution, sufficient comminution of the straw can be obtained simply by mixing said straw with solid and/or liquid manure before it is introduced into the fermenter, because the urea contained therein can already macerate the lignin structures. It not even absolutely necessary for the straw to be mixed with liquid manure or solid manure before introduction into the fermenter, but it may be sufficient to pile the straw and solid material up in alternating layers in the fermenter, optionally interspersed with layers of other, non-lignified renewable raw materials, with the urea of the upper solid manure layers penetrating together with the percolate into the layer of ligneous material, thus at least partly releasing the flat lignin structures. This constitutes an extremely simple example of chemical comminution.

[0111] Although a preferred exemplary embodiment is shown in the drawings and described in detail, this should be consider purely as an example which by no means limits the scope of the invention. It should be noted that only the preferred exemplary embodiment is shown and described, and all changes and modifications, which currently or in the future fall within the scope of the invention are protected.

List of Reference Nos.

[0112]

10	Biomass power plant
12	Basic section
14	Expansion section
16	Fermenter
18	Fermenter forecourt
20	Fermenter door
22	Electricity and heat production system
24	Delivery and loading area
26	Fermenter forecourt hall section
28	Delivery and loading area hall section
30	Technical scaffold

31	Exhaust cooling area
32	Film gas storage unit
34	Percolate circulation tank
36	Southern technical area
38	Northern technical area
40	Roof lights
42	Delivery bunker for fresh mass
44	Conveyor belt
46	Fresh mass bunker
48	Supply area
50	Bale delivery area
52	Comminution area
54	Interim storage unit
56	Roller conveyer
58	Bale channel
60	Digestate bunker
62	Bulk trough for digestate
64	Switch for digestate
66	Conveyor belt for digestate
68	Loading silos for digestate
70	Dehydration device
72	Straw bales
74	Underside of straw bale 72
76	Upper side of straw bale 72
78	First set of holes
80	Second set of holes
82	Device for saturated steam treatment
83	Lid
84	Pressure container
85	Hinge
86	Central gas distribution storage unit
87	Supply device
88	Engine installation room
89	Container
90	Ventilation engine installation rooms
91	Closing mechanism
92	Exhaust engine installation rooms
93	Supply line
94	Docking station
95	Supply valve

96	Storage unit
97	Outlet line
98	Outlet valve
100	Compressor
102	Saturated steam
103	Outcoming saturated steam
104	Device for saturated steam treatment
106	Ligneous renewable raw material
108	Pressure-tight slider
110	Funnel
112	Steam reservoir
114	Heater
116	Conveyor belt
117	Slurry
118	Pipe connection
120	Line to the PCT
122	Device for saturated steam treatment
124	Spike
126	Internal cavity
128	Opening in the spike 124
130	Device for saturated steam treatment
132	Crane
134	Trolley
136	Frame
138	Gripper for upper bale
140	Gripper for lower bale

BIOGÁZ ÜZEM, VALAMINT ELJÁRÁS BIOGÁZ ELŐÁLLÍTÁSÁRA LIGNINTARTALMÚ MEGÚJULÓ NYERSANYAGOKBÓL

Szabadalmi igénypontok

1. Biogáz üzem (10) biogáz előállítására, amely tartalmaz legalább egy fermentort biomassza anaerob bakteriális erjesztéséhez, valamint (a) berendezést szalma mechanikai feltárásához, amely berendezésnek szalma őrléssel, előnyösen kalapácsos darálóval megvalósított őrléssel történő mechanikai aprítására szolgáló szerkezete van, továbbá (b) berendezést (82, 104, 122, 130) szalma telítettgőzös-kezeléssel („Sattdampfbehandlung") vagy nyomás alatt végzett termikus hidrolízissel (Thermodruckhydrolyse") történő termikus feltárásához.

2. Az 1. igénypont szerinti biogáz üzem, amely tartalmaz továbbá berendezést szalma kémiai feltárásához, amely berendezésnek szalma vízben, vizes-savas oldatban, vizes-lúgos oldatban, szűrletben vagy hígtrágyában való áztatására szolgáló tartálya van.

3. Az 1. igénypont szerinti biogáz üzem (10), amely biogáz szilárdanyag-erjesztő eljárással történő előállítására alkalmasan van kialakítva, továbbá több fermentort (16) tartalmaz.

4. Az 1. igénypont szerinti biogáz üzem (10), ahol a telítettgőzös-kezelésre szolgáló berendezésnek (82, 104, 122, 130) nyomástartálya (84), továbbá a nyomástartályban (84) 20 bar és 30 bar közé eső nyomású, valamint 180°C és 250°C közé eső hőmérsékletű vízgőz előállítására alkalmas eszközei (112, 114) vannak.

5. A 4. igénypont szerinti biogáz üzem (10), ahol a nyomástartályban (84) ömlesztett szalma tárolására alkalmas vízgőzáteresztő tartály (88) van elrendezve.

6. Az 5. igénypont szerinti biogáz üzem (10), amelynek egy a vízgőzáteresztő tartály (89) nyomástartályba (84) való bevitelére és nyomástartályból való eltávolítására szolgáló eszköze (87) van.

7. Az 5. igénypont szerinti biogáz üzem (10), ahol a vízgőzáteresztő tartálynak (89) egy a vízgőzáteresztő tartály ömlesztett szalmával történő megtöltését lehetővé tevő felső nyílása, továbbá egy az ömlesztett szalma vízgőzáteresztő tartályból (89) történő távozását lehetővé tevő alsó nyílása van.

8. Az 1-7. igénypontok bármelyike szerinti biogáz üzem (10), ahol a telítettgőzös-kezelésre szolgáló berendezésnek (130) egymással csővezetékekkel összekötött több nyomástartálya (84) van.

9. Az előző igénypontok bármelyike szerinti biogáz üzem (10), ahol a szalma mechanikai és termikus feltárására, valamint adott esetben kémiai feltárására szolgáló berendezések egy szállító- és töltőterületen (24) vannak elrendezve, ahol a szállító- és töltőterület (24) célszerűen folyamatos anyagmozgatással (44, 46, 56) rendelkezik, ami alkalmas friss massza szállító- és töltőterületről (24) fermentor-előtérbe (28) továbbítására, amelyből több garázs-típusú fermentor (16) érhető el.

10. A 9. igénypont szerinti biogáz üzem (10), ahol a szállító- és töltőterület (24) a friss massza számára előnyösen első anyagmozgató-eszközökkel (44) ellátott legalább egy beépített szállítótárolóval (42) rendelkezik, az első anyagmozgató-eszközök a friss masszának a friss massza legalább egy

szállítótárolójából (42) frissmasszatárolóba (46) való továbbítására alkalmasan vannak kialakítva, ahol az első anyagmozgató-eszközöknek olyan szállítószalagjuk (44) van, melyen a frissmasszatárolóba (46) különböző szállítótárolókból (42) friss massza továbbítható.

11. A 10. igénypont szerinti biogáz üzem (10), amely második anyagmozgató-eszközökkel, előnyösen tolólappal rendelkezik, melyek a friss masszának a frissmasszatárolón (46) át a fermentor-előtér (18) irányába történő továbbítására alkalmasan vannak kialakítva.

12. A 9. vagy a 10. igénypont szerinti biogáz üzem (10), amelynek szalmabála ürítő állomása van, ahol az ürítőállomáson szalmabálák megragadására és továbbítására alkalmasan kialakított daru (132) van elrendezve.

13. A 12. igénypont szerinti biogáz üzem (10), amelynek különálló bálák vagy bálacsomagok bálacsatorna (58) mentén a fermentor-előtérbe (18) való továbbítására alkalmasan kialakított görgős vagy fiókos anyagmozgató-eszköze van.

14. A 12. vagy a 13. igénypont szerinti biogáz üzem (10), amelynek egy a bálacsatorna (58) fermentor-előtérhez (18) közeli végén elrendezett, továbbá bálacsomagoknak a bálacsatornából (58) való eltávolítására és kiszerelésként kerekes rakodógépre vagy villástargoncára való átrakására alkalmasan kialakított átrakodója van.

15. A 10-14. igénypontok bármelyike szerinti biogáz üzem (10), ahol a szállítótároló (42) és/vagy a frissmasszatároló (46) és/vagy a bálacsatorna (58) célszerűen egy vagy több gázmotor hulladékhőjével fűthetőn van/vannak kialakítva.

16. Az előző igénypontok bármelyike szerinti biogáz üzem (10), amelynek erjesztmény bejuttatásához egy a fermentor-előtérből (18) megközelíthető erjesztménytárolója (60) van, ahol az erjesztménytárolónak (60) az erjesztmény erjesztménytárolón (60) keresztüli továbbítására alkalmasan kialakított anyagmozgató-eszközei, előnyösen folyamatos anyagmozgató-eszközei vannak, amely folyamatos anyagmozgató-eszközök előnyösen az erjesztménytároló (60) végén elrendezett szállítócsigákat tartalmaznak.

17. A 16. igénypont szerinti biogáz üzem (10), ahol az erjesztménytároló (60) a biogázrendszerhez van csatlakoztatva.

18. A 16. vagy a 17. igénypont szerinti biogáz üzem (10), ahol az erjesztménytároló (60) belépővégén erjesztmény hordalékkád (62) van elrendezve.

19. A 16-18. igénypontok bármelyike szerinti biogáz üzem (10), ahol az erjesztménytároló (60) kilépővégén egy az erjesztmény dehidratálására szolgáló berendezés (70) van elrendezve.

20. Az előző igénypontok bármelyike szerinti biogáz üzem (10), amelynek fagáz, illetve szegénygáz szárított erjesztményekből faelgázosító eljárással való előállítására szolgáló elgázosító berendezése van.

21. Az előző igénypontok bármelyike szerinti biogáz üzem (10), amelynek az erjesztmények szárításához dob- vagy szalagszárítót tartalmazó, az erjesztmények víztartalmát 25% alá csökkentőn szárító szárítóberendezése van.

22. Eljárás biogáz előállítására szalmából, amelynek keretében
a szalmát mechanikai és termikus feltárása eléréséhez előkezelésnek vetjük alá, ahol
a szalma mechanikai feltárását a szalma őrlésével, előnyösen kalapácsos darálóval megvalósított őrlésével végezzük, továbbá
a termikus feltárást telítettgőzös-kezeléssel vagy nyomás alatt végzett termikus hidrolízissel végezzük,
az előkezelt szalmát fermentorba juttatjuk (16) és
a fermentorban (16) anaerob bakteriális erjedést lehetővé körülményeket hozunk létre.

23. A 22. igénypont szerinti eljárás, amelynél a szalmát vízben, vizes-savas oldatban, vizes-lúgos oldatban, szűrletben vagy hígtrágyában áztatva kémiai feltárásnak is alávetjük.

24. A 22. igénypont szerinti eljárás, amelynél a szalma őrlését por állagú konzisztencia eléréséig folytatjuk.

25. A 22. igénypont szerinti eljárás, amelynél a telítettgőzös-kezelést a szalma ligninstruktúráját feláztatón, ugyanakkor a szalma külső struktúráját összességében lényegében egybentartón végezzük.

26. A 22. igénypont szerinti eljárás, ahol a nyomás alatt végzett termikus hidrolízist a szalmában lévő lignint kioldón, továbbá a szalmában lévő polimereket a víz és hő fizikai hatásával monomerekre felbontón hajtjuk végre.

27. A 22-26. igénypontok bármelyike szerinti eljárás, amelynél a telítettgőzös-kezelést 160°C és 240°C közé eső hőmérsékleten, valamint 20 bar és 30 bar közé eső nyomáson 20 percnél rövidebb ideig végezzük.

28. A 22-26. igénypontok bármelyike szerinti eljárás, amelynél a nyomás alatt végzett termikus hidrolízist 160°C és 240°C közé eső hőmérsékleten, valamint 20 bar és 30 bar közé eső nyomáson 60-120 percig végezzük.

29. A 22-28. igénypontok bármelyike szerinti eljárás, amelynél a telítettgőzös-kezelés végén a kezelőnyomást 5 másodpercen belül legalább 80%-kal csökkentjük.

30. A 22-29. igénypontok bármelyike szerinti eljárás, amelynél a szalmát a telítettgőzös-kezelést megelőzően beáztatásnak vetjük alá.

31. A 22-30. igénypontok bármelyike szerinti eljárás, amelynél a szalmát a telítettgőzös-kezelést követően savas oldatban, előnyösen szűrletben, lúgos oldatban vagy hígtrágyában áztatjuk.

32. A 22-31. igénypontok bármelyike szerinti eljárás, amelynél az előkezelés befejezését követően és az anaerob fermentálás megkezdését megelőzően a szalmához semmilyen további savat, enzimet, gombát vagy élesztőt nem adunk hozzá.

33. A 22-32. igénypontok bármelyike szerinti eljárás, amelynél az erjesztményt víztartalmát 25% alá, előnyösen 15% alá csökkentve szárítjuk, továbbá fagázzá, illetve szegénygázzá elgázosítjuk.

34. A 23. igénypont szerinti eljárás, amelynél szilárdanyag-erjesztést alkalmazó biogáz üzemek esetében a kémiai feltárást a szalmának az erjesztett massza fermentorba juttatását megelőző szilárd trágyával, hígtrágyával, szűrlettel és/vagy szűrlet tartalmú erjesztett masszával való összekeverésével valósítjuk meg.

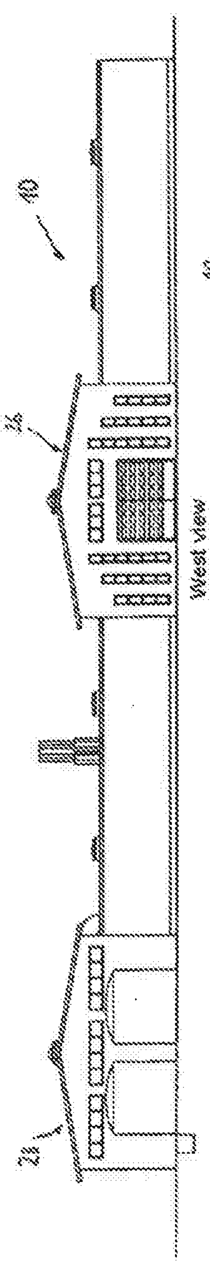

Fig. 1

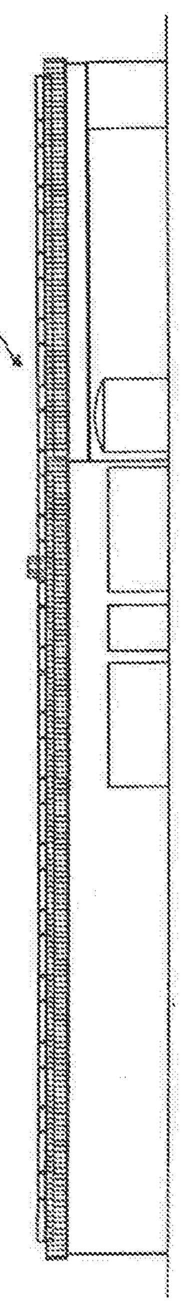

Fig. 2

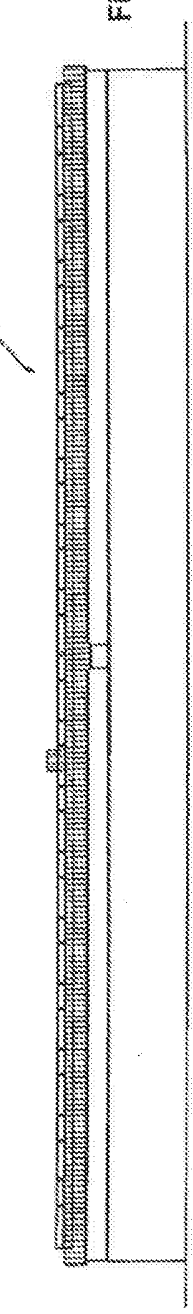

Fig. 3

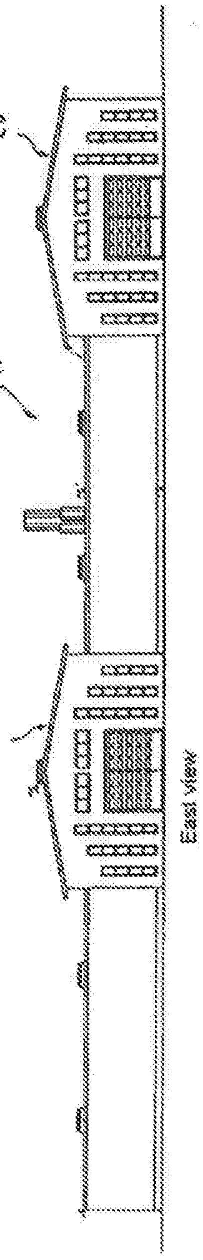

Fig. 4

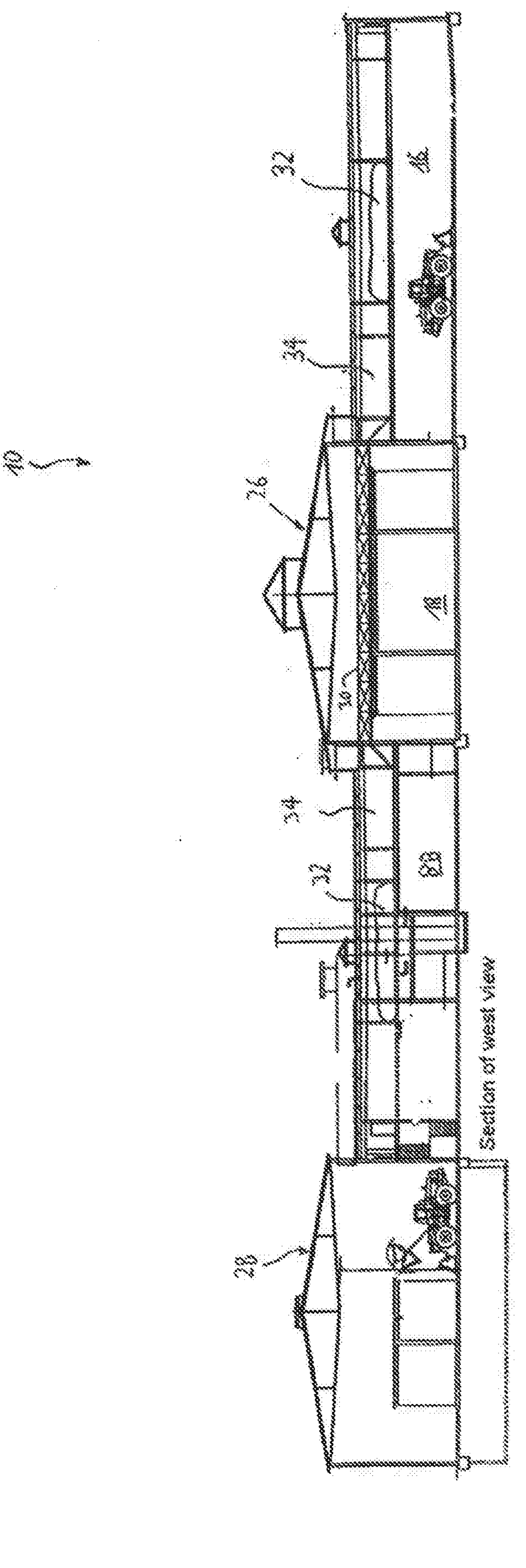

Fig. 5

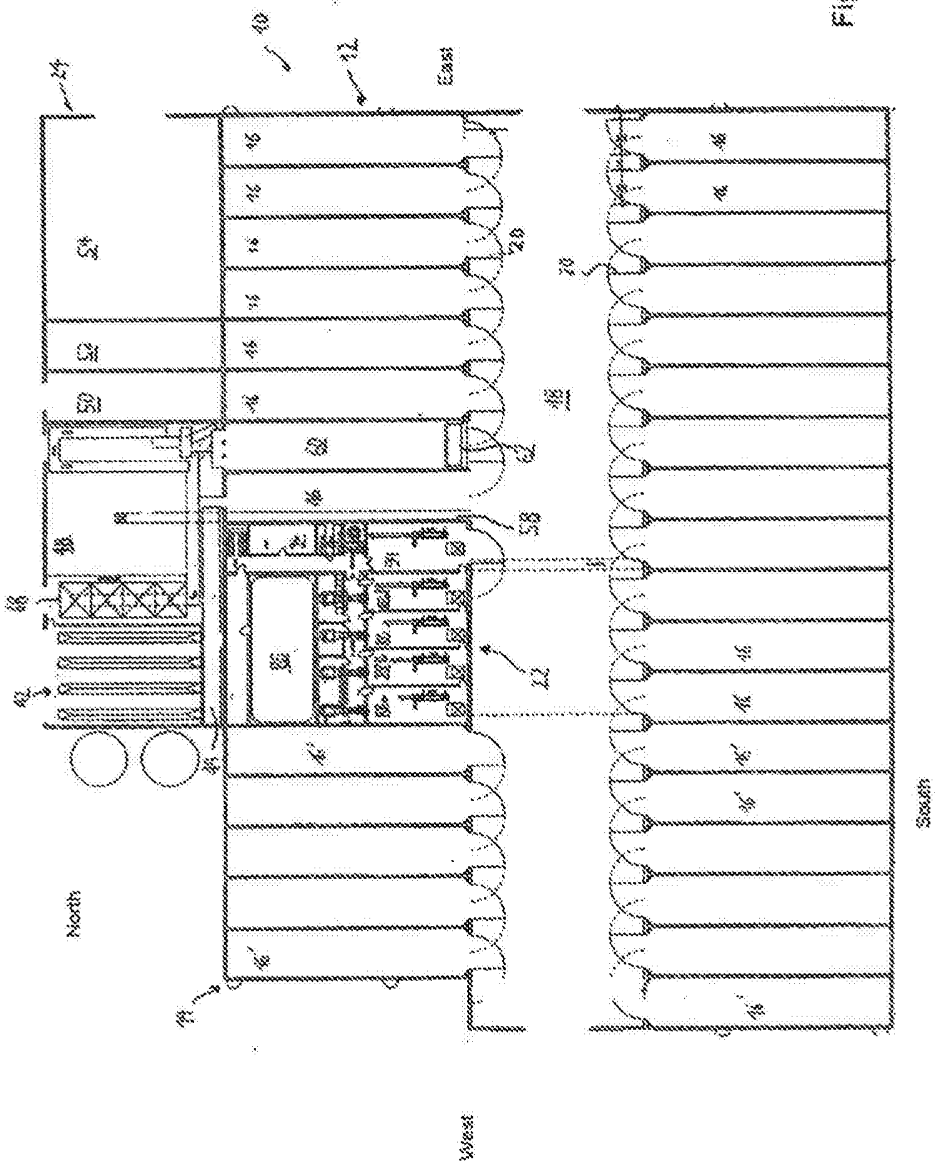

Fig. 6

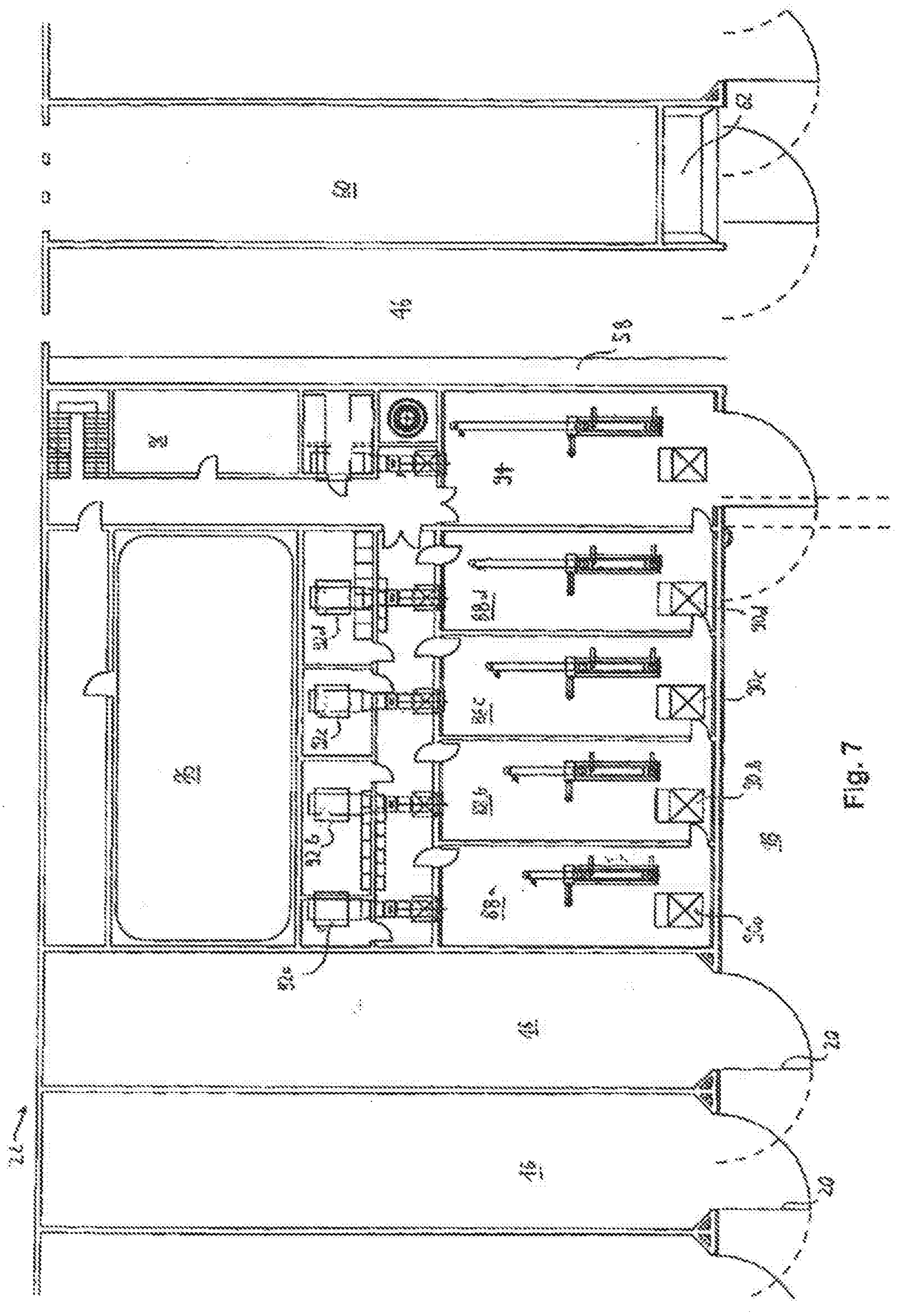

Fig. 7

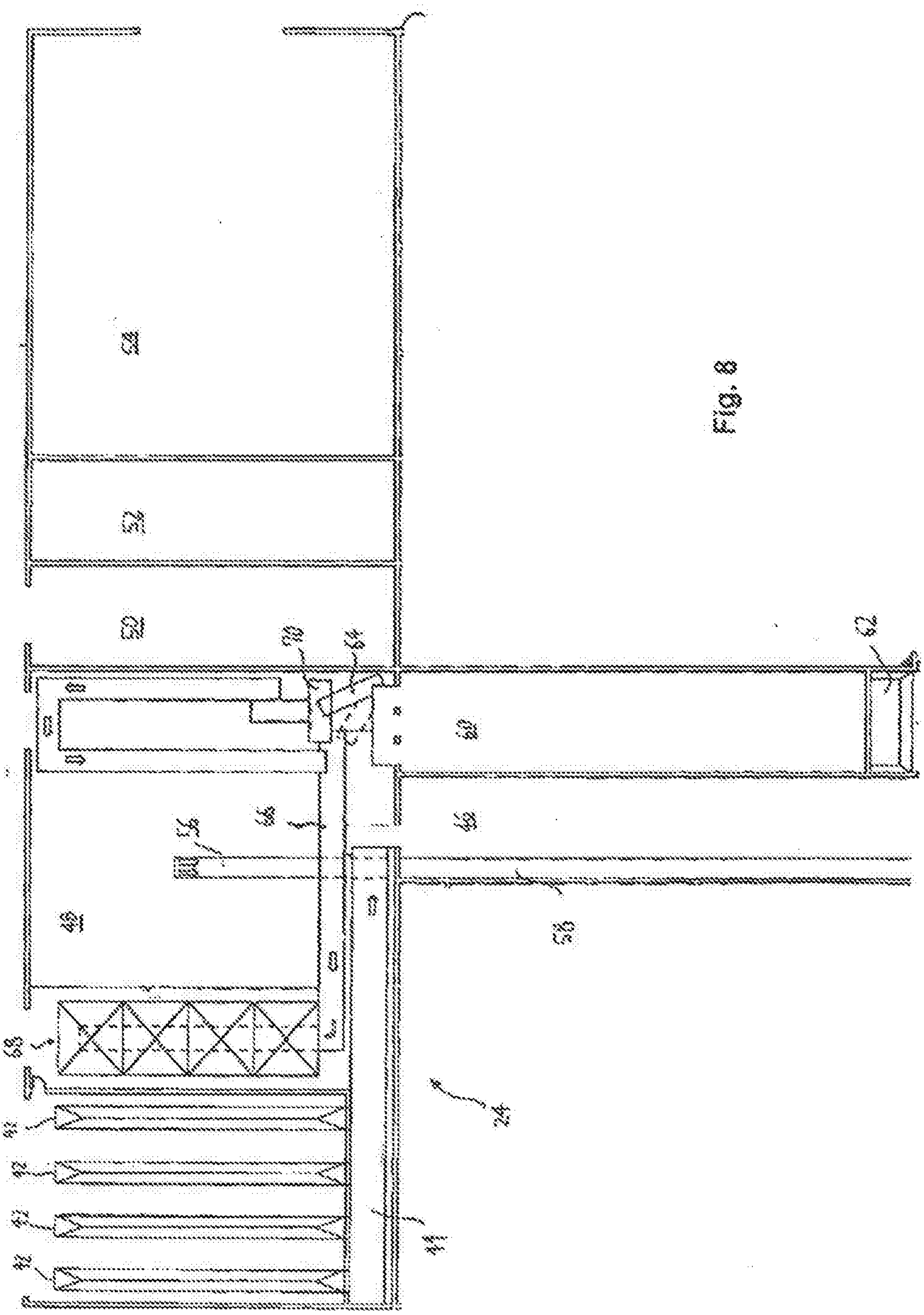

Fig. 8

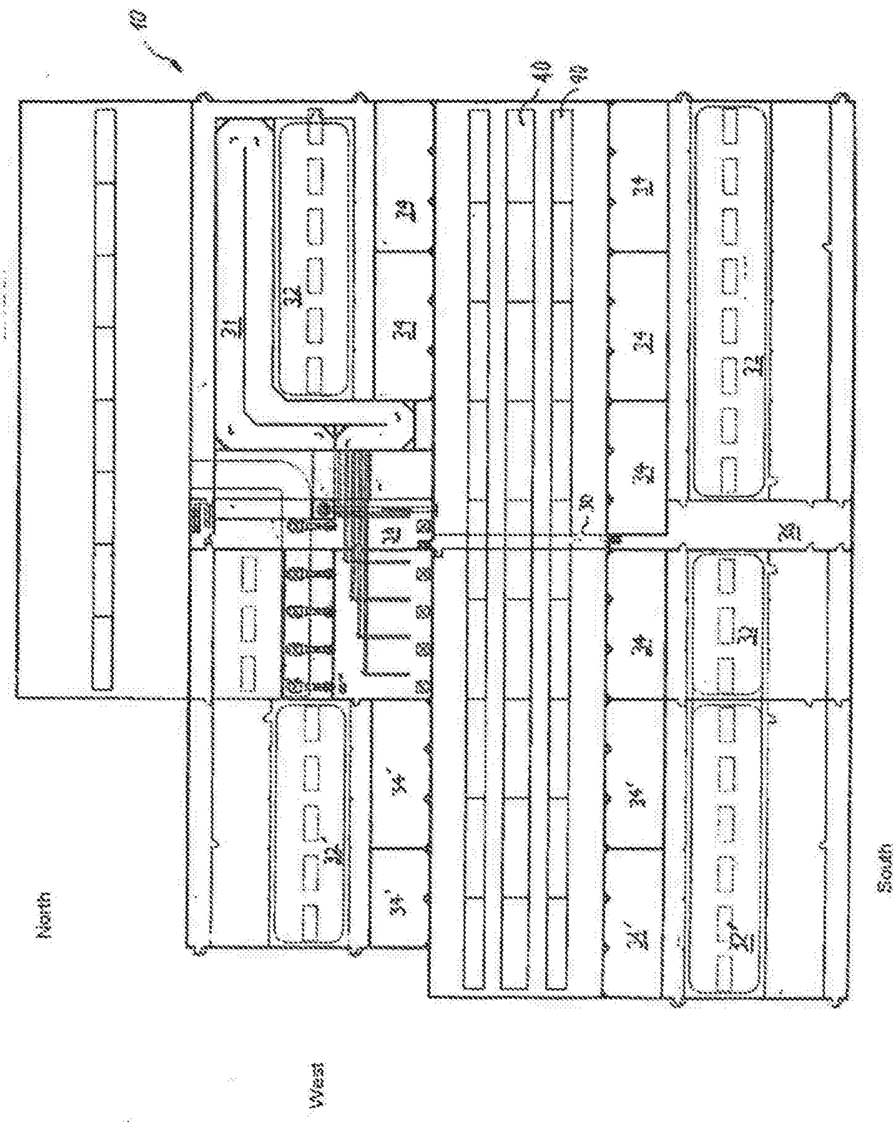

Fig. 9

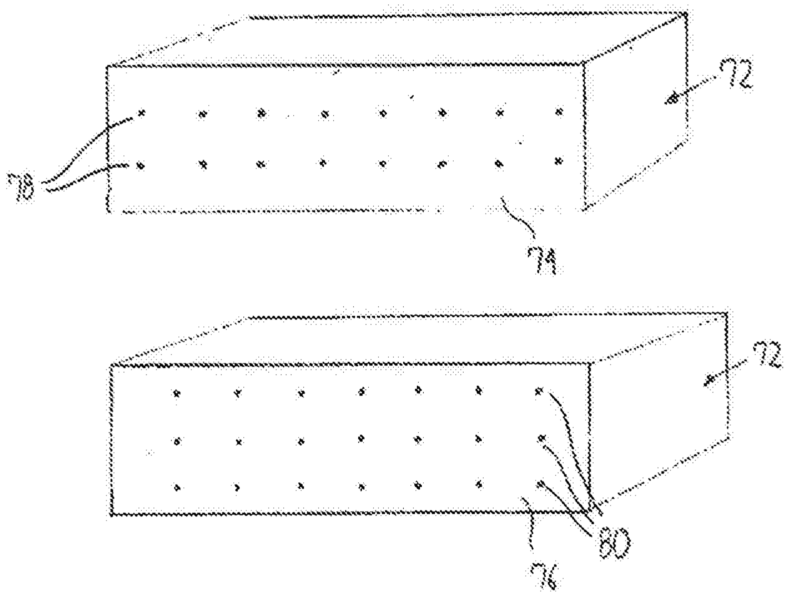

Fig. 10

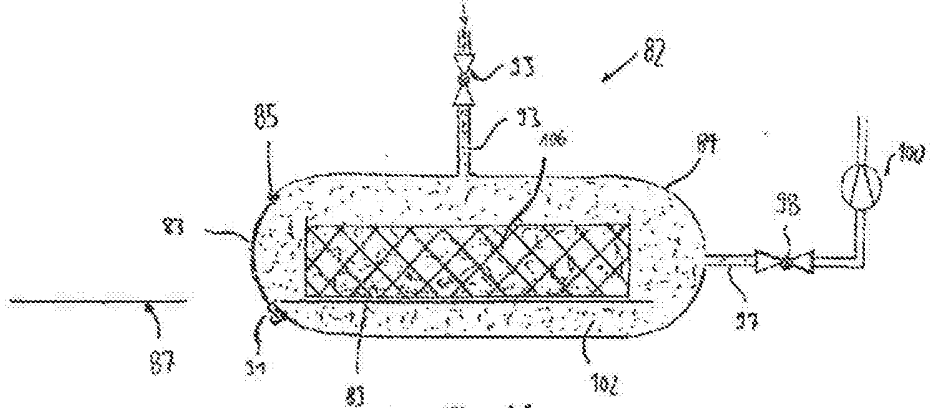

Fig. 11

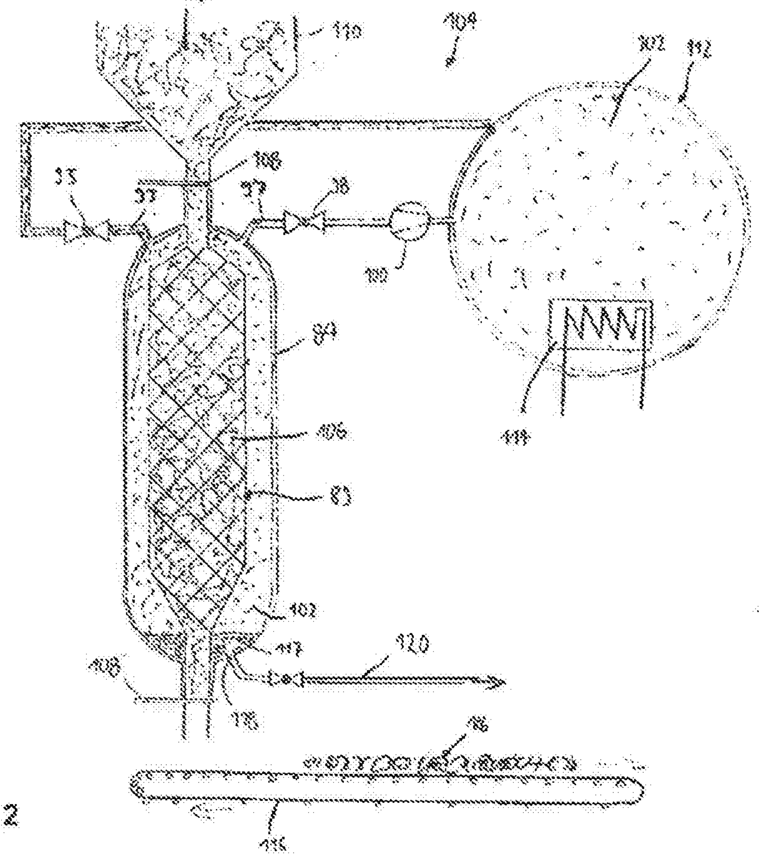

Fig. 12

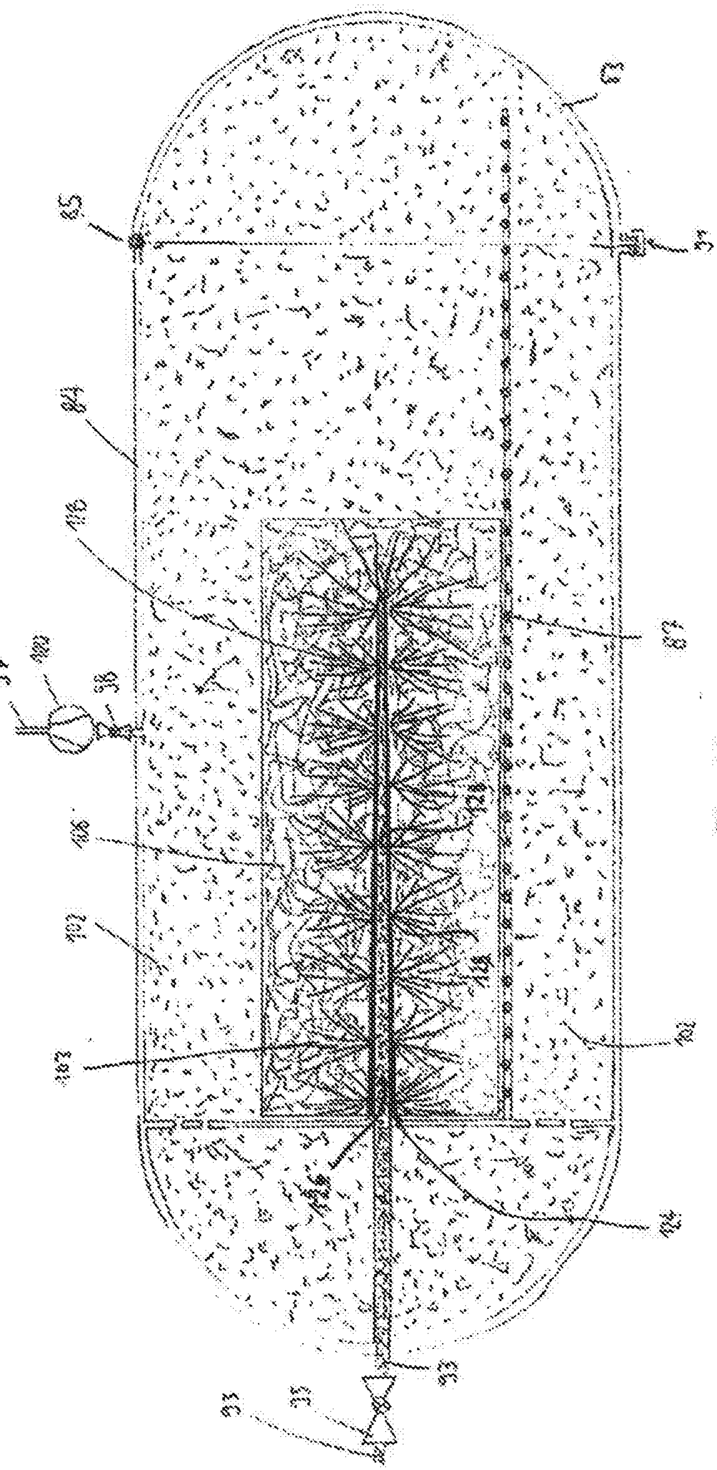

Fig. 13

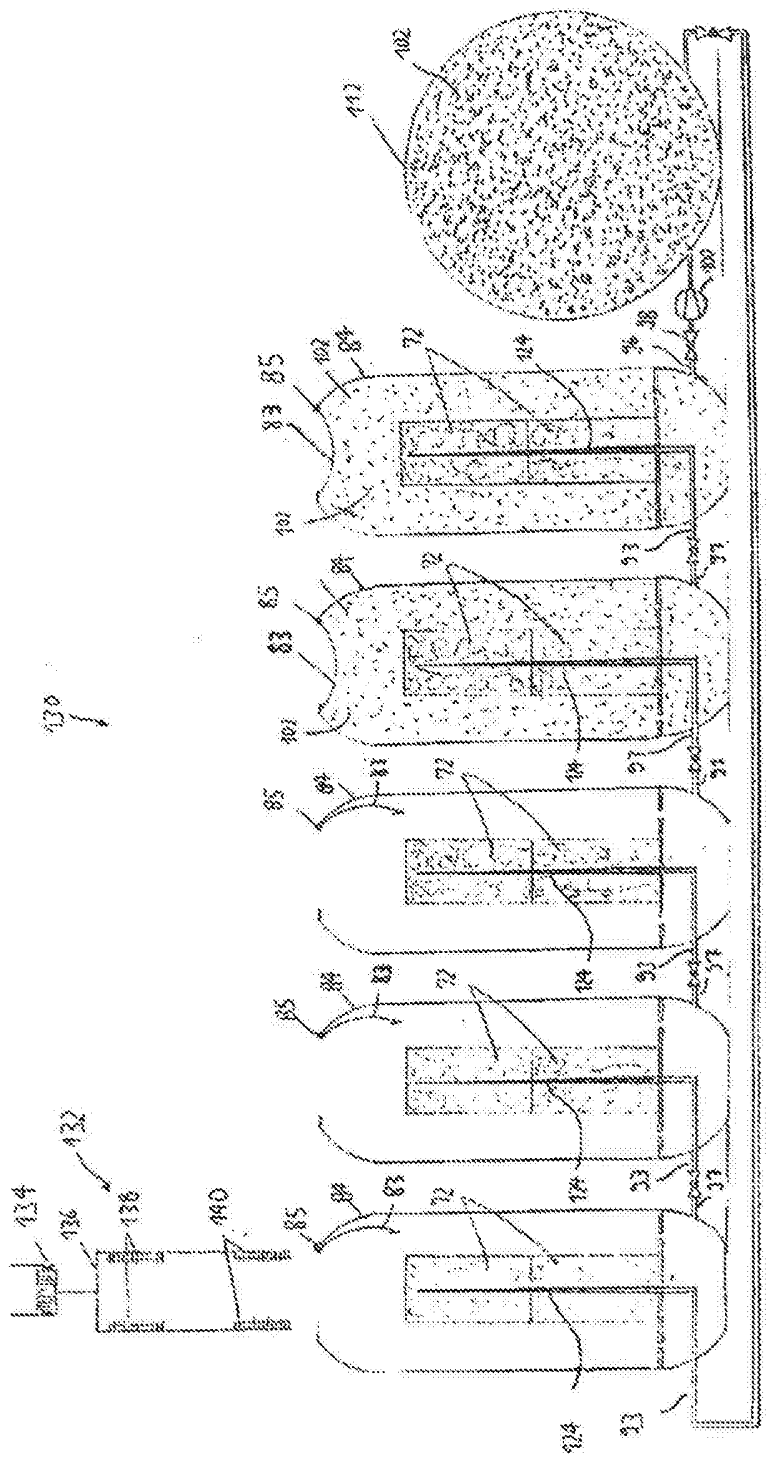

Fig. 14