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(54) METHOD AND DRYING PLANT MATERIAL AND UTILISING HEAT FROM THE DRYING PLANT

(57) A method and a plant for utilising heat from a drying plant for drying material in the form of particulate material, e.g. wood chips, shavings, sawdust, straw, wood pellets or bedding, including bedding that has been used in a stable. The method and the plant include a drying step for drying the particulate material, which is heated by hot oil. A boiler for heating the oil is connected with means for supplying at least a partial stream of the material to the boiler for burning the material in the boiler. In addition, the boiler has means for transmitting the combustion heat from flue gas to the oil before the oil is returned to the drying chamber. The plant also includes a heat exchanger by which a partial stream of the hot oil from the boiler is heating a circulating heating medium, such as water, from a heating conduit of the heating part of a central heating system for heating and/or hot water production for one or more buildings. In front of the heat exchanger there is preferably provided a condenser condensing vapour in the drying air and transmitting the heat to the heating medium for preheating and utilisation of the heat from the drying air.

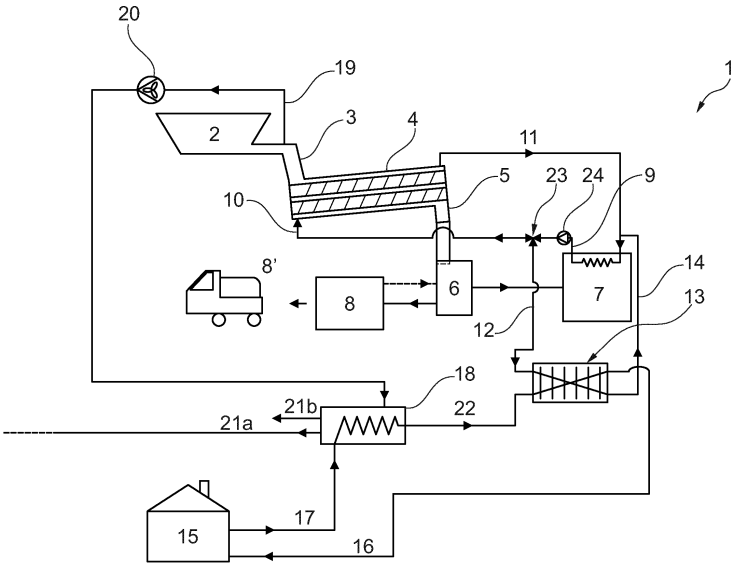


Fig. 1

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Description

Field of the Invention

[0001] The present invention concerns a drying plant for drying material in the form of particulate material, preferably of biological origin, such as wood chips, shavings, sawdust, straw, wood pellets or bedding, including bedding that has been used in a stable, wherein the drying plant is arranged for utilising heat from the drying plant.

[0002] The present invention also concerns a method for drying material in the form of particulate material, preferably of biological origin, such as wood chips, shavings, sawdust, straw, wood pellets or bedding, including bedding that has been used in a stable, and for utilising heat from the drying plant.

Background of the Invention

[0003] In housing and/or industrial buildings that do not have access to district heating or gas it is necessary to ensure heating of the building by other energy sources. It is e.g. often the case in areas with agricultural buildings lying scattered and sometimes isolated, and the energy providers have therefore decided not to lay district heating or gas supply networks in such areas.

[0004] These buildings are therefore to be heated by alternative energy sources, e.g. large straw-fired plants that can heat housing as well as industrial buildings on the estate.

[0005] Alternatively is used an automatic stoker fired with particulate, solid (biological) fuel in the form of wood pellets, wood chips, sawdust, shavings, corn, etc., which is fed into the boiler by the automated stoker. The stoker uses one or more screw conveyors for transporting and dosing the fuel to the boiler for burning and generating heat and/or hot water for the building(s) on the estate.

[0006] This type of plants are usually cheap as the price of fuel is low compared with fossil fuels. However, regular deliveries of fuel are required in order to ensure sufficient heating of the building(s) of the estate.

[0007] Alternatively, the estate is to have the capability to provide fuel, e.g. corn or wood chips, by itself in order to ensure sufficient energy supply for heating and hot water supply on the estate.

[0008] This can often be associated with problems as possible suitable biofuel from own production of the estate can have a relatively high moisture content and is therefore not suited to be fed to the stoker and into the boiler without previous drying, since wet fuel may cause clogging in the conveyor systems of the stoker and since wet fuel may cause problems in the boiler by incomplete/bad combustion and problems with soot and/or disruption of operation as a consequence.

[0009] An example of material not currently used as fuel due to high water content is used bedding from stables. Bedding is e.g. wood shavings, wood chips, sawdust, wood pellets or other pellet-shaped material of other organic materials, e.g. straw, paper and the like. This type of bedding is currently used as an alternative to straw in stables, e.g. in poultry and horse stocks, as bedding based on e.g. wood shavings or wood pellets normally gives off less dust than straw and therefore provide a better indoor climate.

[0010] After use in the stable, the bedding is gathered. Due to the content of animal excrements and/urine, the used bedding cannot normally be used without further treatment and is today to be disposed of. The material can e.g. be delivered to a biogas plant that converts the bedding and the manure to biogas. However, it is associated with substantial costs as there may be large amounts of used bedding to be removed, typically by lorries.

[0011] Therefore, there is a demand for utilising this waste flow locally on the estate so that transporting large amounts of used bedding for disposal is avoided.

[0012] Today there are plants on the market that can dry organic material such that it is suited as biofuel.

[0013] CN203298580U describes a drying screw for drying organic manure where the heat is recovered and utilised in the circulating medium by means of a heating tank. Suction is applied on the drying drum and evaporation of liquid from the material to be dried occurs at low temperature and low pressure. There are no indications of recover of residual or waste heat.

[0014] US2013/0014678A1 describes a drying screw drying waste water sludge in a first drying step and in a second drying step. After the first drying step where the sludge is dried into a paste-like consistency, the sludge is subsequently extruded into pellets and is then dried in a second drying step. Pellets are combusted in a boiler. The drying screw in the first drying step uses oil or water vapour as heat transmission medium. Oil/vapour can be heated by heat exchange with hot air from the second drying step and by heat exchange with the gas from the combustion of the pelletised and dried sludge. Vapour from the drying screw is condensed, and the heat is transmitted to drying air in second step. Excess heat from the process is used internally in the plant.

[0015] DE 3911716 A describes a plant with drying screw drying sludge, bedding and the like with e.g. oil as circulating heat transmission medium. The oil is circulated in the jacket around the screw and is heated up to about 250°C in the boiler. The motor is directly connected to the screw via diverse couplings and transmissions. Vapour from the drying step is used as heating source in preheating the sludge in the heat exchanger, which is preheating the sludge before it is conducted to the drying screw. There is no recovering or utilisation of residual or waste heat.

[0016] Thus there is a need for better utilisation of waste heat and/or residual heat in the drying plant.

Object of the Invention

[0017] It is thus an object of the invention to provide a

method and a plant for drying particulate material and which will utilise waste and/or excess heat efficiently.

[0018] It is therefore also an object of the invention to enable enhanced utilisation of waste and/or residual heat in drying plants and to apply the heat locally for heating in the buildings of an estate.

[0019] It is therefore also an object of the invention to enable utilisation of waste flows of used bedding locally on the estate so that transportation of large amounts of used bedding for disposal is avoided.

Description of the Invention

[0020] These objects are achieved by a plant for utilising heat from a drying plant for drying material in the form of particulate material, preferably of biological origin, such as wood chips, shavings, bedding, including bedding that has been used in a stable. The plant includes a drying step for drying the particulate material, which is heated by a heating medium in the form of oil. The plant further includes a boiler for heating the oil and is connected with means for supplying at least a partial stream of the material to be dried to the boiler for burning the material in the boiler. The boiler includes means for transmitting the combustion heat from flue gas to the oil before the oil is returned to the drying chamber. In addition, the plant includes a heat exchanger, which with a partial stream of the heated oil from the boiler is used for heating a circulating heating medium, such as water, from a heating conduit in the heating part of a central heating system for heating and/or hot water production for one or more buildings.

[0021] The object of the invention is further achieved by a plant for utilising heat from a drying plant for drying material in the form of particulate material, preferably of biological origin, such as wood chips, shavings, and bedding, including bedding that has been used in a stable. The method includes drying the particulate material in a drying step using the circulating oil. At least a partial stream of the material to be dried is then supplied to the boiler for burning the material in the boiler and transmission of combustion heat from flue gas to the oil before the oil is returned to the drying step. A partial stream of the oil from the boiler is diverted for heating a circulating heating medium, such as water, in a heat exchanger, the heating medium coming from a heating conduit in heating part of a central heating system for heating and/or hot water production for one or more buildings.

[0022] The heat generated by burning the material to be dried is hereby utilised for generating heat, partly for use in the drying process and partly for heating the circulating heating medium in a heating conduit of a central heating system.

[0023] The material to be dried in fed directly into the drying chamber or preferably into an initial mixer with cutters for comminuting and simultaneous mixing of the material. The mixer is described in more detail below.

[0024] Between the mixer and the drying chamber there is preferably provided a first cellular gate transferring the material to be dried from the outlet of the mixer to the inlet of the drying chamber. This first cellular gate prevents drying air from unhindered getting out of the drying chamber through the inlet.

[0025] The drying chamber preferably includes a horizontal or inclining screw conveyor with a surrounding heating jacket through which the heated oil is circulating, preferably as described in detail below.

[0026] The screw conveyor moves the material to be dried from the inlet of the drying chamber to the outlet of the drying chamber under simultaneous stirring and heating from the heating jacket.

[0027] In order to ensure sufficient air circulation and ample transmission of heat to the drying air in the drying chamber, air is sucked through the drying chamber in direction from the outlet end to the inlet end, preferably by an air pump or a ventilator in the air discharge duct from the drying chamber.

[0028] It is preferred that the air pressure in the drying chamber is maintained around atmospheric pressure in order to reduce leakage of drying air to the surroundings, which may cause smell nuisances. This will also ensure sufficient air circulation in the drying chamber and thereby increased heating of the drying air in the drying chamber, thus entailing enhanced efficiency of the drying step as the air will not be saturated with water vapour before leaving the drying chamber.

[0029] The drying air with increased contents of water vapour is sucked away under weak vacuum, which is preferably up to 0.1 to 0.2 bar, e.g. by a ventilator or a pump. The drying air can then be discharged to the atmosphere or conducted to a condenser which is described in more detail below. During the evaporating of the water in the material to be dried, a slight increase in pressure will occur in the drying chamber due to the increased water vapour pressure. By sucking the drying air out of the drying chamber, the total pressure is lowered to about atmospheric pressure, and the water vapour pressure in the drying chamber is reduced, increasing the drying rate of the material in the drying chamber.

[0030] The material to be dried is preferably also moved out of the drying chamber via a second cellular gate that also prevents the drying air from getting out to the surroundings unhindered through the outlet.

[0031] The second cellular gate transfers dried material to a buffer tank for storage until the material is to be combusted in the boiler. When the control of the automatic stoker calls for fuel, one or more conveyors will move the material into the boiler for burning with subsequent heating of the circulating oil.

[0032] The screw conveyor of the drying step is preferably horizontal or slightly inclining in relation to horizontal such that the outlet of the screw conveyor is above the level of the inlet. The angle of the screw conveyor relative to horizontal of an inclining screw conveyor is preferably 5-25°.

[0033] The size of the plant is dimensioned according

to the amount of material to be treated. Experiments have shown that the material to be dried should have a retention time in the drying chamber of 1-3 hours, preferably about two hours in order to be sufficiently dry for storage and subsequent combustion in the boiler without causing operational problems in the form of clogging and/or soot formation in the boiler.

[0034] In order to make the control as simple as possible, it is preferred that the screw conveyor in the drying chamber runs with constant speed, providing a constant retention time for the material to be dried in the drying chamber. This is an advantage, for example when the plant and the method are used on an agricultural estate where moist, used bedding of animal husbandry is dried by the method and the plant according to the invention. The production of moist, used bedding from animal stock is relatively constant all the year round, and the plant may therefore advantageously be dimensioned to constantly treating the same amount per hour. In summertime, when the demand for heating of buildings is low and the need for generating heat by burning the material to be dried is low, possible surplus production of material is removed from the system, e.g. for storage and/or subsequent production of fuel pellets.

[0035] The screw conveyor in the drying chamber is driven by a motor, preferably an electric motor. The motor drives the shaft of the screw, either via a transmission, e.g. a chain or belt drive, or the motor is mounted directly on the shaft. When the motor is mounted directly on the shaft there is a risk that the heat from the jacket is transmitted via the shaft of the screw conveyor, screw connections etc. into the motor, which may destroy heat-sensitive parts of the motor, e.g. gear, bearings, packings and similar. In order to prevent this, the washers, bushings etc. between the motor and the screw conveyor in the drying chamber are made of a heat-insulating material. The heat-insulating material is e.g. a composite material of e.g. cotton fibres and phenol resin, or polyester fibres and epoxy marketed under the name Etronax ®.

[0036] The oil can circulate through the heat jacket countercurrently or concurrently with the material to be dried, but it is preferred that the oil circulates concurrently with the material since the material supplied to the drying step has the highest water content and thereby also the greatest need for heat transmission in order to evaporate the water in the material.

[0037] The oil is circulated, e.g. by a circulation pump, in that the oil is applied a slight overpressure up to 1 bar, such as 0.3-0.7 bar, or preferably about 0.5 bar, in order to enable circulation of the oil. By keeping the pressure low in the oil, the risk of hazardous situations arising by possible leaks where hot oil can spurt out of the plant and cause personal injury. Moreover, it is avoided that the design of the plant falls within European pressure regulations requiring special approval of the plant.

[0038] Within the heating jacket there is preferably provided a number of flow-directing elements. The flow-directing elements include e.g. round steel rods, radially extending plates, walls or similar. The flow-directing elements are preferably twisted around the screw conveyor such that the oil in the jacket circulates in the jacket in channels between the flow-directing elements, and at the same time such that the oil circulates around the screw conveyor between inlet and outlet for the oil in the heating jacket. These flow-directing elements ensure optimal transmission of heat to the material within the jacket moved by the screw conveyor between the inlet and the outlet of the drying chamber.

[0039] The heating jacket preferably includes an outer insulation layer that insulates against loss of heat to the surroundings.

[0040] The oil introduced in the tubes in the heating jacket around the screw conveyor in the drying chamber is heated in a boiler to 180-200 °C, preferably about 185-195 °C.

[0041] At the outlet of the heating jacket around the screw conveyor in the drying chamber, the oil temperature drops to about 160-180° C, preferably about 165-175° C.

[0042] From the outlet of the heating jacket, the oil is conducted back to the boiler for renewed heating to the operating temperature as described above.

[0043] The boiler is a combustion device for combusting solid fuel in a combustion chamber. In this case, the material to be dried is also used as fuel. However, it is possible to supplement with other fuel sources, e.g. purchased chips or wood pellets if the fuel production in the form of material to be dried is insufficient.

[0044] The boiler transmits heat from the combustion chamber to the oil, heating the latter to about 180-200 °C, as described above.

[0045] As it is preferred that the boiler has automatic feeding and dosing of solid fuel, preferably an automatic stoker is used. The automatic stoker includes conveyors for supplying the solid fuel from a storage container and into the combustion chamber. The storage container is preferably a buffer as mentioned below. The conveyors are preferably one or more screw conveyors feeding the material to be dried into the combustion chamber.

[0046] The oil used as heating medium is a heat-resistant oil that can stand the high temperatures without being decomposed. It is preferred that the oil can stand temperatures up to 300° C.

[0047] A partial stream of the oil leaving the boiler after heating is conducted to a heat exchanger for heat exchange with and heating of a heating conduit from a central heating system used for heating and/or hot water production for buildings, including housing and/or industrial buildings as described in detail above. The oil outflow from this heat exchanger is returned to the boiler where it is heated again as described above.

[0048] At the inlet of the heat exchanger, the partial stream of hot oil from the boiler is about 180-200 °C, preferably about 185-195 °C. At the outlet of the heat exchanger where the hot oil has given off heat to the heating medium from the heating conduit in the central

heating system, the temperature of the oil has dropped to about 160-180° C, preferably about 165-175 °C

[0049] Alternatively, the oil from the outlet of the heating jacket of the drying chamber is conducted into the heat exchanger for heat exchange with and for heating the heating conduit from a central heating system. The cooled oil is conducted from the heat exchanger back to the boiler for renewed heating.

[0050] The heat exchanger is preferably a tube, spiral or plate heat exchanger as it is preferred to use a conventional concurrent or countercurrent heat exchanger approved for heating oil and the above mentioned operating temperatures.

[0051] In a central heating system, a heating medium, typically water, is circulated in a heating conduit where heat is given off to a utility heating line and transmitted to radiators for heating one or more buildings, and/or the water in the heating conduit is conducted to a heat exchanger for heating hot tap water for the taps of the building(s).

[0052] The supply pipe temperature at the inlet of the central heating system after heating the heating medium in the heat exchanger is 60-80° C, preferably about 65-75 °C. The return pipe temperature of the central heating system, i.e. in the heating medium in the heating conduit conducted out from the central heating system, is about 30-50 °C, preferably about 35-45 °C, depending on the heat and/or hot water consumption in the building or buildings. Heating in the heat exchanger and possibly a pre-coupled condenser reduces the emission of unused waste heat to the surroundings, transmitting heat to the heating conduit of the central heating system from an inexpensive form of fuel. The condenser is described in more detail below.

[0053] After preheating and subsequent main heating, the circulating heating medium is returned to the central heating system for giving off heat to the heating conduit to radiators and/or for heating tap water.

[0054] The material to be dried is preferably biological material, preferably vegetable material suited for combustion after preceding drying. Suitable biological material is e.g. wood chips, shavings, sawdust, straw or wood pellets. These may all be used as bedding in a stable with for keeping animals, e.g. in stables for horses, poultry, cattle, sheep, goats and/or pigs etc., as mentioned below. The excrements and/or urine of the animals is mixed with the bedding, considerably increasing the water content of the bedding. The bedding is removed after some days, according to need. Larger or smaller amounts of used bedding with varying water content are generated, depending on the animal species and the number of animals in the stable.

[0055] The water content in used bedding containing animal excrements and/or urine is typically up to 60-70% by weight before drying. After drying, the water content in the material to be dried is reduced to about 1-15% by weight, preferably 1-8% by weight, since a higher water content can lead to possible clogging downstream of the drying chamber when the material has been used as bedding. If the material to be dried is pure wood, such as chippings, sawdust or shavings, which have not been used as bedding before drying, the residual water content can be somewhat higher, typically up to 15% by weight, without causing clogging in the system.

[0056] These types of fuel are inexpensive compared with fossil fuel (calculated per kW heat), and when using dried used bedding from stables, a waste stream is utilised as heat source instead of allocating expenses for disposal of the used bedding. The costs of heating thereby are further reduced, and in addition the expenses for disposal are saved.

[0057] The plant and the method can thereby be used as substitute for gas- or oil-fired central heating systems or as substitute for district heating in areas where gas or district heating is not available.

[0058] It is preferred that the system includes a condenser for condensing water vapour and/or condensable gases from an airflow drawn from the drying chamber, as the heating medium from the heating conduit in the heating part in the central heating system is used as a coolant in the condenser for preheating thereof before the subsequent heating in the heat exchanger.

[0059] It also preferred that the method includes condensable vapours and/or gases from an airflow drawn from the drying step are cooled and condensed in a condenser, as the heating medium in the heating conduit of the heating part of the central heating system is used as coolant in the condenser for preheating the heating medium of the heating conduit before heating in the heat exchanger.

[0060] The temperature of the drying air out of the drying step is in the range 100-180° C, however typically in the lower end thereof if the material to be dried contains much water to be evaporated in the drying step described above.

[0061] The temperature of the heating medium at the inlet to the condenser is normally in the magnitude about 30-50 °C, preferably about 35-45 °C, depending on the heat and/or hot water consumption in the building or buildings. The temperature of the heating medium at the outlet of the condenser is normally about 10°C higher than at the inlet, i.e. 40-60 °C, typically about 40-55°C

[0062] The latent heat in the air discharged from the drying step is utilised hereby, including heat in water vapour from evaporated water from the material and other gases, e.g. ammonia, in the air flow, as the heat is used for preheating the heating medium in the heating conduit from the central heating system. Thereby is utilised the heat that otherwise would be wasted if the drying air is just discharged to the atmosphere from the drying step.

[0063] The condenser is preferably a heat exchanger where the cooled heating medium from the heating conduit in the central heating system is conducted countercurrently to the air discharged from the drying step. Suitable heat exchangers are e.g. plate heat exchangers or heat exchangers of the radiator type, including particu-

larly tube heat exchangers with fins at the outer side of the tubes.

[0064] The cooled heating medium from the heating conduit of the central heating system is conducted within the tubes and heated by the drying air on the jacket side. The drying air thereby gives off heat to the heating medium within the tubes, and the vapour in the drying air is condensed on the fins.

[0065] At the inlet to the condenser, the cooled heating medium from the heating conduit in the central heating system is about 30-50 °C, preferably about 35-45 °C, as mentioned above. At the outlet of the condenser, the now preheated heating medium from the heating conduit in the central heating system is heated about 10°C compared with the inlet, and the temperature at the outlet of the condenser is therefore about 40-60 °C, preferably about 45-55 °C, in that the rise in temperature has occurred by transmission of heat and condensation of water vapour from the drying air into water. The waste heat in the drying air is thereby utilised for preheating the heating medium before heating to the supply pipe temperature in a heat exchanger by heat exchange with a partial stream of the hot oil from the boiler.

[0066] The heating medium is then conducted to the heat exchanger where it is further heated by heat exchange with a partial stream of the hot oil from the boiler, as described above.

[0067] If the material to be dried is bedding that has been used in a stable with animal husbandry and therefore contains excrements and/or urine from the animals, e.g. horses, poultry, sheep, goats, cattle and/or pigs etc. the drying air will also include gases, e.g. ammonia, hydrogen sulphide and other gases that may produce smell nuisances to the surroundings. When the water vapour is condensed from the drying air in the condenser, it can be drained off to sewer or be collected, utilised in other ways, e.g. as irrigation water for plant crops, water for flushing stable equipment and other purposes. Moreover, at large part of possible extant ammonia and possibly other gases in the drying air, including possible extant hydrogen sulphide, will be washed out of the drying air by means of the condensate in the condenser. Ammonia and possible hydrogen sulphide can thereby be collected and their fertilising value utilised, e.g. by using the condensate as irrigation water for crops on e.g. fields and or in greenhouses.

[0068] It is preferred that a mixer is provided before the drying chamber, such as a conveyor with a double screw, for mixing and simultaneous reducing the particle size of the material to be dried.

[0069] In the method it is also preferred that a mixer is provided before the drying chamber, such as a conveyor with a double screw, for mixing and simultaneous reducing the particle size of the material to be dried.

[0070] The material to be dried is therefore preferably fed into an initial mixer with cutters for comminuting and simultaneous mixing of the material. The initial mixer is e.g. a container, e.g. with one or two inclining bottom sides, where at the bottom of the container there is arranged a double screw, and where the screw conveyors have cutters such that they can cut up and at the same time comminute the material to be dried while they mix and transport the material to the outlet of the container. The screw conveyors in the mixer are preferably driven by each their motor.

[0071] By the method a partial stream of the material can be taken out for subsequent pelletisation. Excess material can thereby be further treated at times where the amount of material to be dried exceeds the fuel consumption of the boiler.

[0072] The second cellular gate transfers dried material to a buffer tank for storage until the material is to be combusted in the boiler. The buffer tank is preferably a container with an inclining wall acting as a slide such that the material to be dried slides towards the bottom of the buffer tank.

[0073] When the control of the automatic stoker calls for fuel, an inclining screw conveyor will move the material up from the bottom of the buffer tank and into the boiler, possibly via one or more additional conveyors, for combustion and concomitant heating of the circulating oil, as described above.

[0074] By excess production of dried material, e.g. at summertime, when the need for heating in buildings is low, the material will fall down into the buffer tank via the second cellular gate. When the buffer tank is full, possible excess production of dried material will be removed by a transvers screw conveyor.

[0075] The transverse screw conveyor is preferably disposed under the cellular gate and above the buffer tank.

[0076] The transverse screw conveyor preferably runs with constant speed and is activated simultaneously with the second cellular gate. When the buffer tank is full and material stands up to the casing around the transverse conveyor, the latter can move dried material out of the plant. When the buffer tank is about to be filled, the material will just fall past the rotating transverse screw conveyor and down into the buffer tank. This construction entails that only dried material is discharged from the plant when the buffer tank is full. Moreover, the construction is simple and reliable, does not require pre-programmed control and means for controlling the operation of the transverse screw conveyor.

[0077] Alternatively, the transverse screw conveyor can be activated when it is detected that the buffer tank is full, e.g. in that material is standing up to the casing around the transverse conveyor. It is possible to use one or more level sensors in order to detect the level of material and to activate the transverse screw conveyor when the buffer tank is full. The transverse screw conveyor moves dried material out of the plant for further treatment, e.g. for pressing into fuel pellets, storage and/or transport away from the plant.

[0078] Alternatively, the transverse conveyor is mounted with one end inside the upper part of the buffer tank.

When the transverse conveyor is activated, and the level in the buffer tank is so high that it is completely or partially covered, it is activated as described above.

Description of the Drawing

[0079] The invention will now be explained in detail with reference to the drawing, where:

- Fig. 1 shows a diagram of a drying plant with heat recovery;
- Fig. 2 shows the part elements of the drying plant that treat, transport and burn material to be dried, in perspective view;
- Figs. 3-4 show the mixer as viewed from one end and in cross-section on the line D-D in Fig. 3, respectively;
- Figs. 5-6 show the drying chamber with screw conveyor and heating jacket and a detail of the connection between screw conveyor and motor, respectively,
- Figs. 7-8 show outlet from drying step to buffer tank as viewed from one end and in cross-section on the line E-E in Fig. 7, respectively.

Detailed Description of Embodiments of the Invention

[0080] Fig. 1 shows a diagram of the drying plant 1 with recovery of heat from drying air and transmission of heat to a central heating system (not shown) for heating and/or hot water production in one or more buildings 15.

[0081] In the following, the plant and the method are described with drying of used bedding in the form of wood shavings. Used bedding in the form of wood shavings containing animal excrements and/or urine has a water content that typically is up to 60-70% by weight before drying. After drying, the water content in the material is reduced to about 1-5% by weight. As mentioned above, other materials can be dried in the plant as well, and the invention is therefore not limited to drying used bedding.

[0082] The material to be dried is fed into the plant to a mixer 2. In the mixer 2, the material is mixed and comminuted as described below. The material is conveyed from the mixer 2 via a first cellular gate 3 into the drying chamber 4 itself as described in detail below.

[0083] The dried bedding is conveyed from the drying chamber 4 via a second cellular gate 5 into a buffer tank 6.

[0084] The buffer tank 6 constitutes a fuel storage for a boiler 7 for an automatic stoker with means for automatic feeding of fuel to the boiler 7. The automatic stoker 7 has automatic control of the fuel supply.

[0085] At times with a surplus production of material compared with the fuel consumption in the boiler, a part of the material is moved to storage and/or subsequent pelletisation 8. The material can be moved away 8' from storage 8, e.g. after the making of pellets. It is possible that stored and/or pelletised dried bedding is returned (shown by broken line arrow in Fig. 1) to the buffer tank 6 at times where the drying chamber is not in operation, e.g. by service, repair or similar.

[0086] The dried bedding is burned in the boiler 7 of the automatic stoker, and the heat is transmitted to oil circulating through the boiler for heating. The heated oil then returns to the drying chamber 4 via an oil inlet 10 to the heating jacket 32 of the drying chamber 4 (not shown on Fig. 1, see Fig. 5), returning to the boiler of the automatic stoker via an oil return line 11 from the heating jacket 32 of the drying chamber 4 (shown on Fig. 5) to the boiler 7 of the automatic stoker.

[0087] At the outlet of the boiler, the hot oil from the boiler has a temperature about 180-200 °C, preferably about 185-195 °C, or particularly about 190°C. At the outlet of the heating jacket 32 of the drying chamber 4 where the hot oil has given off heat to the material to be dried, the temperature of the oil has dropped to about 160-180° C, preferably about 165-175 °C, or particularly about 170°C.

[0088] The oil is circulated by a circulation pump 24. The circulation pump applies the oil a slight overpressure up to 1 bar, such as 0.3-0.7 bar, or preferably about 0.5 bar, sufficient to circulate the oil in the plant.

[0089] A partial stream 12 of the hot oil flow 9 from the boiler is conducted to a heat exchanger 13, preferably a plate heat exchanger, preferably a concurrent or countercurrent heat exchanger. The partial stream is preferably taken out by a three-way valve 23 with an actuator (not shown) which is activated when a temperature sensor in the heat exchanger 13 calls for heat. When the oil leaves the heat exchanger 13 it has given off heat to the water in the heating conduit from the central heating system, and the temperature of the oil has dropped to about 160-180°C, preferably about 165-175°C, or particularly about 170°C. The oil is conducted via a return 14 back to the automatic stoker boiler for renewed heating together with return 11 of the oil from the drying chamber 4.

[0090] In a not shown variant, no partial stream of hot oil is diverted for the heat exchanger 13. Instead, the oil return 11 or a partial stream thereof from the drying chamber is directed into the heat exchanger 13 before returning to the boiler of the automatic stoker 7 for renewed heating in the boiler.

[0091] An example of suitable oil is e.g. Termway® from Statoil that can stand temperatures up to 300°C.

[0092] A heating medium, preferably water, is heated in the heat exchanger 13, circulating in a heating conduit of a central heating system (not shown) in a building 15. The central heating system provides heat and/or hot water for use in one or more buildings 15 that may be housing and/or industrial buildings, e.g. buildings in operation on a farm. The return flow 17 in the heating conduit to the central heating system is thus conducted into the heat exchanger 13 from the central heating system at a temperature of about 30-50 °C, preferably about 35-45 °C, depending on the heat and/or hot water consumption in the building or buildings. After heating the heating medi-

um in the heat exchanger 13 to a temperature of about 60-80°C, preferably about 65-75°C, the heating medium is conducted via return 16 back to the central heating system for giving off heat in the central heating system.

[0093] The drying air is conducted out of the drying chamber 4 via an air discharge duct 19. A ventilator or air pump 20 is located in the air discharge duct, sucking drying air out of the drying chamber 4 such that no overpressure is formed caused by evaporated water and emission of other fluid components in gas form to the drying air in the drying chamber 4.

[0094] The drying air can be discharged to the surroundings if so desired (not shown on Fig. 1).

[0095] The drying air has a high content of water vapour, and the temperature of the drying air is in the range 100-180°C. Therefore it is possible to recover the heat from the drying air and the energy of the vapour in the drying air by condensing the water vapour and to recover the energy of condensation heat from the drying air.

[0096] It is therefore preferred that the discharge duct 19 of the drying air is directed to a condenser 18. The condenser 18 is a heat exchanger as it is preferred to use a tube heat exchanger with fins at the outer side of the tubes.

[0097] The cooled heating medium in the return 17 from the heating conduit of the central heating system is conducted within the tube side and heated by the drying air on the jacket side in the condenser 18. The drying air thereby gives off heat to the heating medium within the tubes, and the vapour in the drying air is condensed on the fins.

[0098] Cooled drying air 21a and condensed water 21b leave the condenser 18 in two separate streams 21a and 21b. The condensate 21b can be conducted to sewer (not shown) or used on the estate, e.g. as irrigation water for crops. The cooled drying air 21a is discharged to the ambient surroundings. When the material to be dried is used bedding, the condensate will include components, e.g. nitrogen (ammonia), having value as fertiliser, why it is possible to collect or use the condensate as irrigation water with fertilising value.

[0099] At the inlet to the condenser 18, the cooled heating medium in the return 17 from the heating conduit the central heating system is about 30-50°C, preferably about 35-45°C, as mentioned above. At the outlet from the condenser, the now preheated heating medium for flow 16 in the heating conduit in the central heating system is now heated about 10°C compared with the inlet 17, and the temperature at the outlet of the condenser 18 is therefore about 40-60°C, preferably about 45-55°C, in that the rise in temperature has occurred by transmission of heat and condensation of water vapour from the drying air into water.

[0100] The heating medium in the return line 17 is then conducted to the heat exchanger 13 via piping 22, where it is further heated by heat exchange with a partial stream 12 of the hot oil from the boiler 7 as described above.

[0101] Fig. 2 shows the components treating and/or transporting material to be dried in the mentioned sequence from left to right, i.e. the mixer 2, first cellular gate 3 (not visible on Fig. 2), drying chamber 4, second cellular gate 5, buffer tank 6 and boiler 7, including one or more conveyors 25 that move dried material into the boiler 7 of the automatic stoker.

[0102] The mixer 2, see in particular Figs. 3-4, is an inclining container with sloping sidewalls 28 acting as a funnel for the material when it is thrown into the mixer 2. Two first screw conveyors 26 are mounted at the bottom of the mixer container 2 in an upwardly open screw channel (not shown). The screw conveyors 26 preferably have cutters along the periphery of the helical carrier such that the material is cut at the same time as it is conveyed towards the outlet (not shown) of the mixer 2. The screw conveyors are driven by each their motor 27. The outlet is disposed at the upper end of the inclining mixer 2.

[0103] The material thereby falls out of the outlet from the mixer 2 and down into the first cellular gate 3 from where it is transferred to the inlet 29 of the drying chamber 4 at the first end 4' of the drying chamber.

[0104] The drying chamber 4 is shown in Figs. 5-6. A second screw conveyor 31 is mounted in a casing that includes a heating jacket 32 through which the hot oil is circulating. The inlet 29 conducts material to be dried into the drying chamber 4 and the screw conveyor 31.

[0105] The hot oil from the boiler 7 (shown in Fig.1) is conducted through the heat jacket 32 for heating and consequent drying of the material in the drying chamber 4. Hot oil is conducted into the heat jacket 32 at the inlet end 4' of the drying chamber for material to be dried and conducted out of the heat jacket at the outlet end 4" for the material to be dried as described above.

[0106] In the heating jacket 32 preferably there is provided a number of flow-directing elements 33. The flow-directing elements 33 include e.g. round steel rods, radially extending plates, walls or similar.

[0107] The flow-directing elements 33 are preferably twisted around the inner wall of the heating jacket 32 which lies against the screw conveyor 31. The flow-directing elements 33 thereby entail that the oil in the heating jacket 32 is moved in the channels appearing between the flow-directing elements 33, and at the same time so that the oil circulates around the screw conveyor 31 between inlet and outlet (not shown on Figs. 5-6) for the oil in the heating jacket.

[0108] A drive motor 36 for rotating the screw conveyor 31 is mounted on the shaft 34 of the screw. The helical carrier 35 moves the material to be dried from the inlet 29 to the outlet 30 by rotation of the screw conveyor 31.Since the motor 36 is mounted directly on the shaft 34 of the screw conveyor there is a risk that the heat from the heating jacket 32 travels via the shaft of the screw conveyor, screw connections and out into the motor. In order to prevent this, washers, bushings 37', 37", 37"' etc. between the motor 36 and the screw conveyor 31 in the drying chamber 4 are made of a heat-insulating material. The heat-insulating material is preferably a com-

posite material of e.g. cotton fibres and phenol resin, or polyester fibres and epoxy, marketed under the name Etronax ®.

[0109] Figs. 7-8 show the outlet 30 from the drying chamber 4 of the material. A second cellular gate 5 moves dried material from the outlet 30 of the drying chamber and down into the buffer tank 6.

[0110] The buffer tank 6 is preferably a container with an inclining sidewall 38 acting as bottom in the buffer tank 6. A third screw conveyor 25 is mounted along the bottom 38 of the buffer tank 6. The third screw conveyor 25 transfers dried material to the boiler 7 of the automatic stoker for burning the material, possibly via one or more further conveyors 25', 25" (see Fig. 2).

[0111] When the buffer tank 6 is full, possible excess production of dried material will be removed by a fourth transverse screw conveyor 39. The transverse screw conveyor 39 is preferably disposed under the cellular gate 5 and above the buffer tank 6.

[0112] The transverse screw conveyor 39 preferably runs constantly simultaneously with the second cellular gate 5. When the buffer tank 6 is full, and material is standing up to the casing around the transverse conveyor 39, the conveyor 39 can move dried material out from the plant 1. When the buffer tank 6 is about to be filled, the material will just fall past the rotating transverse screw conveyor 39 and down into the buffer tank 6. This construction provides that only dried material is discharged from the plant when the buffer tank is full. Moreover, the construction is simple and reliable, does not require pre-programmed control and means for controlling operation of the transverse screw conveyor 39.

[0113] Alternatively, the transverse screw conveyor 39 can be activated when it is detected that the buffer tank 6 is full, e.g. in that material is standing up to the casing around the transverse conveyor 39. One or more level sensors are used in order to detect the level of material and to activate the transverse screw conveyor 39 when the buffer tank 6 is full.

[0114] The transverse screw conveyor 39 moves dried material out of the plant 1 for further treatment 8, e.g. for pressing into fuel pellets, storage and/or transport 8' away from the plant 1 (shown on Fig. 1).

Example

[0115] In a plant with a drying chamber with a length of 6 m and a diameter of 800 mm, about 30 kW heating is supplied. In the drying chamber, used and moist bedding from a horse stable is dried to a water content of 1-5% by weight.

[0116] The plant has capacity for producing about 1500 kg dried used bedding a day. Of this about half is burned in the boiler, and therefore about 750 kg dry matter is yielded per day, which is reworked by pelletisation.

[0117] The screw conveyor in the drying chamber rotates rather slowly, and the rotational speed can be set such that the retention time in the drying chamber is about 2 hours. The boiler has a capacity of 140 kW.

[0118] The plate heat exchanger is a conventional plate heat exchanger with a capacity of 125 kW.

[0119] About 15 kW is recovered in the condenser by cooling of drying air and condensation of the water vapour in the drying air in the condenser.

[0120] The energy production of the plant, which is transmitted to the heating circuit of the central heating system, provides heating and hot water production for 1200m^2 buildings.

Claims

1. A drying plant (1) for drying material in the form of particulate material, preferably of biological origin, such as wood chips, shavings, sawdust, straw, wood pellets or bedding, including bedding that has been used in a stable, wherein the drying plant is arranged for utilising heat from the drying plant, the plant including:

   - a drying chamber (4) for drying the particulate material, which is heated by a circulating flow (9, 11) of oil;
   - a boiler (7) for heating the oil and connected with means (6) for supplying at least a partial stream of the material to the boiler (7) for burning the material in the boiler (7), and with means for transmitting the combustion heat from flue gas to the oil before the oil is returned to the drying chamber (4), the plant also including
   - a heat exchanger (13), which with a partial stream (14) of the oil from the boiler (7) is used for heating a circulating heating medium, such as water, from a heating conduit (16, 17) of the heating part of a central heating system for heating and/or hot water production for one or more buildings (15).

2. A drying plant according to claim 1, **characterised in that** the plant includes a condenser (18) for condensing water vapour and/or condensable gases from an airflow (19) drawn from the drying chamber (4), as the heating medium from the heating conduit (17) in the heating part in the central heating system is used as a coolant in the condenser (18) for preheating thereof before heating in the heat exchanger (13).

3. A drying plant according to claim 1 or 2, **characterised in that** the drying chamber (4) includes a horizontal or inclining screw conveyor with a surrounding heating jacket (32) through which the heated oil is circulating, preferably concurrently with the material to be dried.

4. A drying plant according to any of claims 1-3, **char-**

acterised in that a mixer (2) is provided before the drying chamber (4), including cutter means for mixing and reducing the particle size of the material to be dried.

5. A method for drying material in the form of particulate material, preferably of biological origin, such as wood chips, shavings, sawdust, straw, wood pellets or bedding, including bedding that has been used in a stable, and for utilising heat from the drying plant, the method including:

- drying the particulate material in a drying step (4) while using a circulating flow of oil (9, 11);
- adding at least a partial stream of the material to the boiler (7) for burning the material in the boiler (7), and transmitting combustion heat from flue gas to the oil before the oil is returned to the drying chamber (4); and
- drawing a partial stream (14) of the oil from the boiler (7) for heating a circulating heating medium, such as water, in a heat exchanger (13), the heating medium coming from a heating conduit (16, 17, 22) of heating part of a central heating system for heating and/or hot water production for one or more buildings (15).

6. A method according to claim 5, **characterised in that** condensable vapours and/or gases from an airflow (19) drawn from the drying chamber (4) are cooled and condensed in a condenser (18), as the heating medium in the heating conduit (17) of the heating part of the central heating system is used as coolant in the condenser (18) for preheating the heating medium of the heating conduit before heating in the heat exchanger (13).

7. A method according to claim 5 or 6, **characterised in that** a mixer (2) is provided before the drying chamber (4), such as a conveyor with a double screw, including cutter means for mixing and reducing the particle size of the material to be dried.

8. Method according to any of claims 5-7, **characterised in that** a partial stream of the material is taken out for subsequent pelletisation (8).

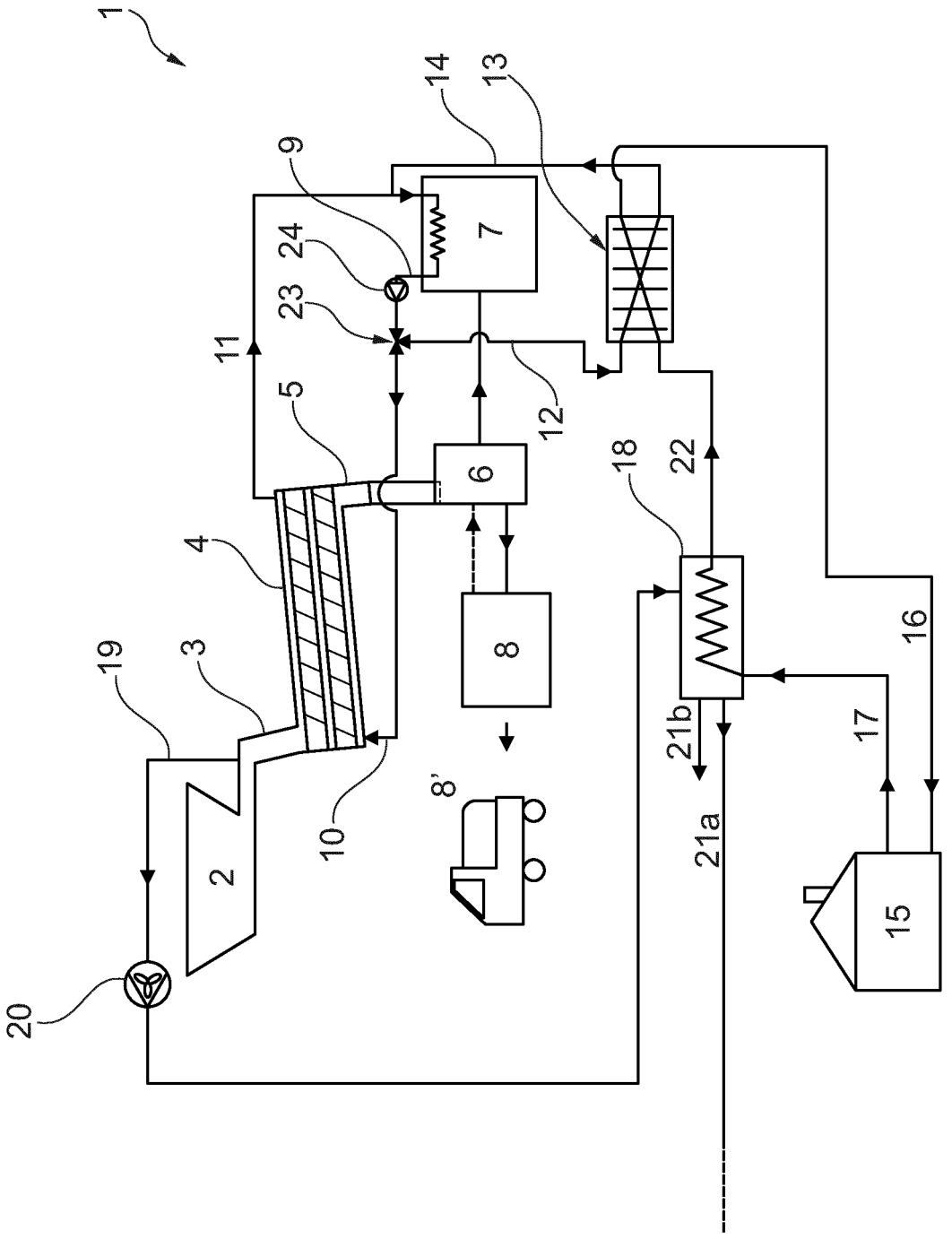


Fig. 1

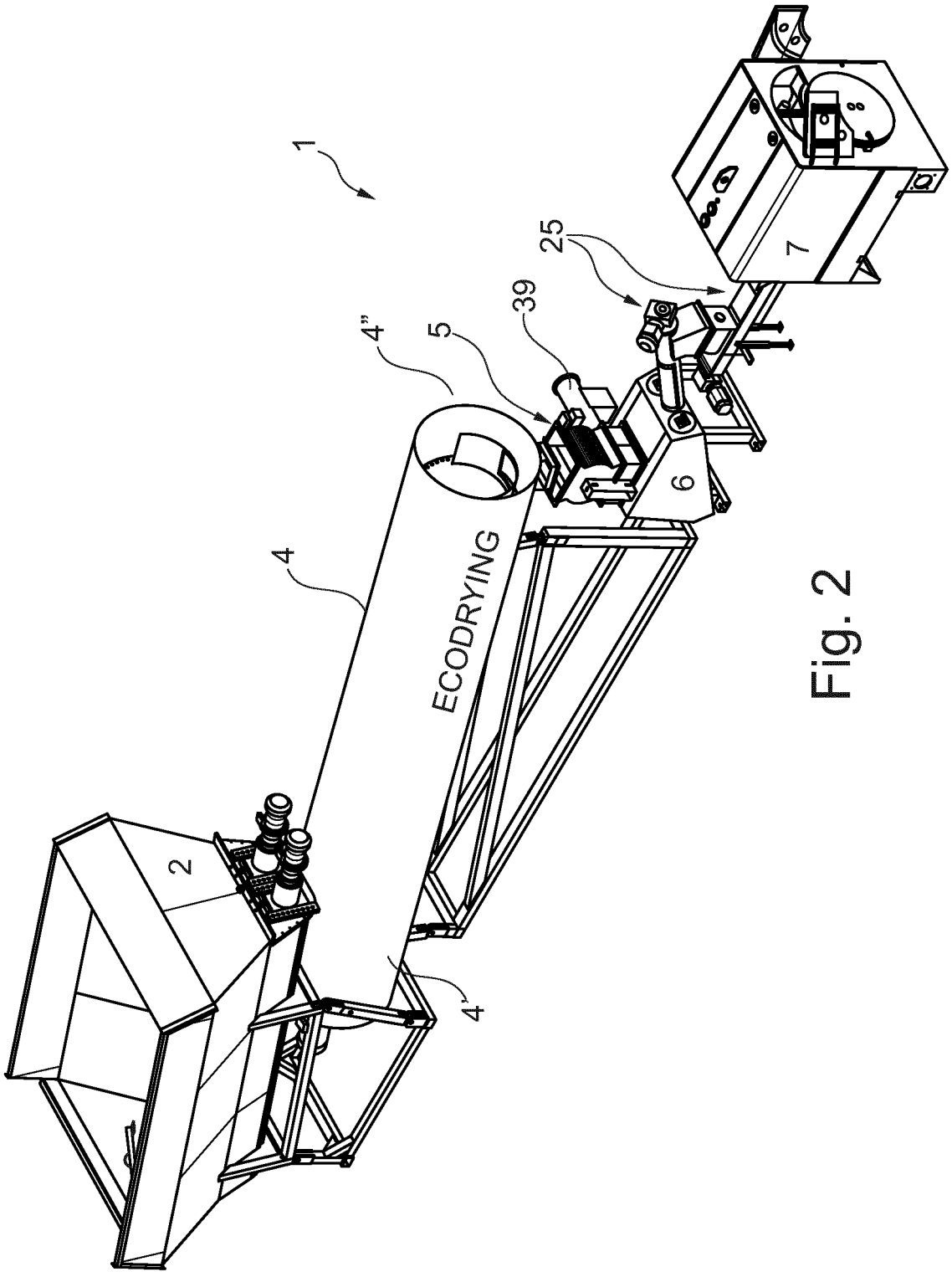


Fig. 2

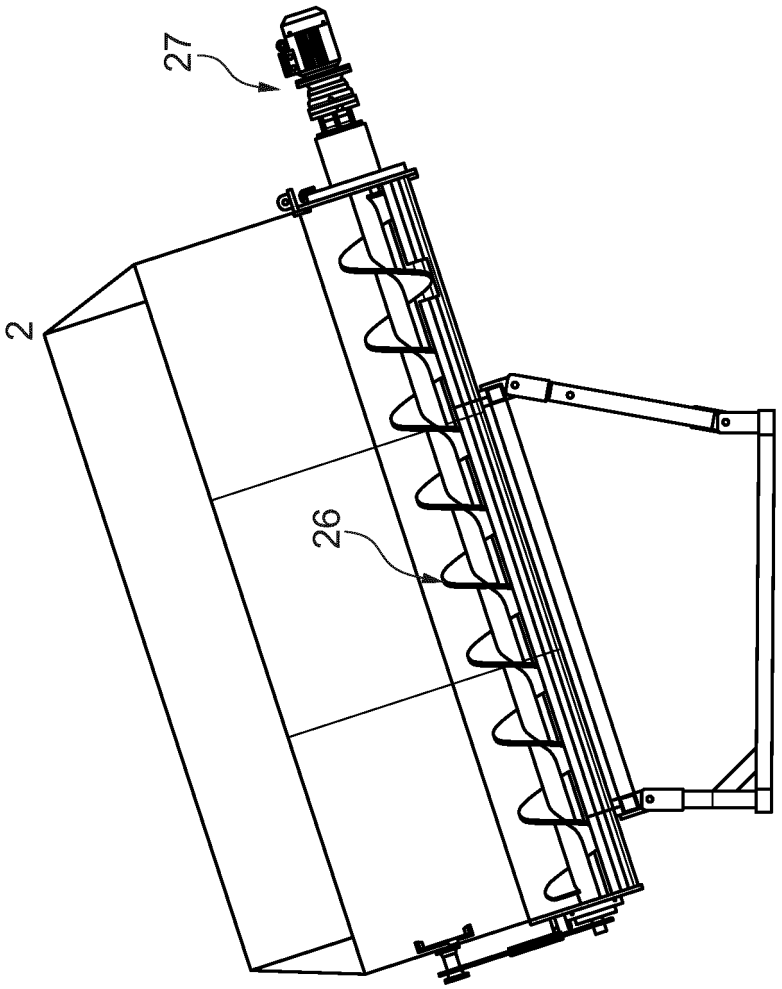


Fig. 4

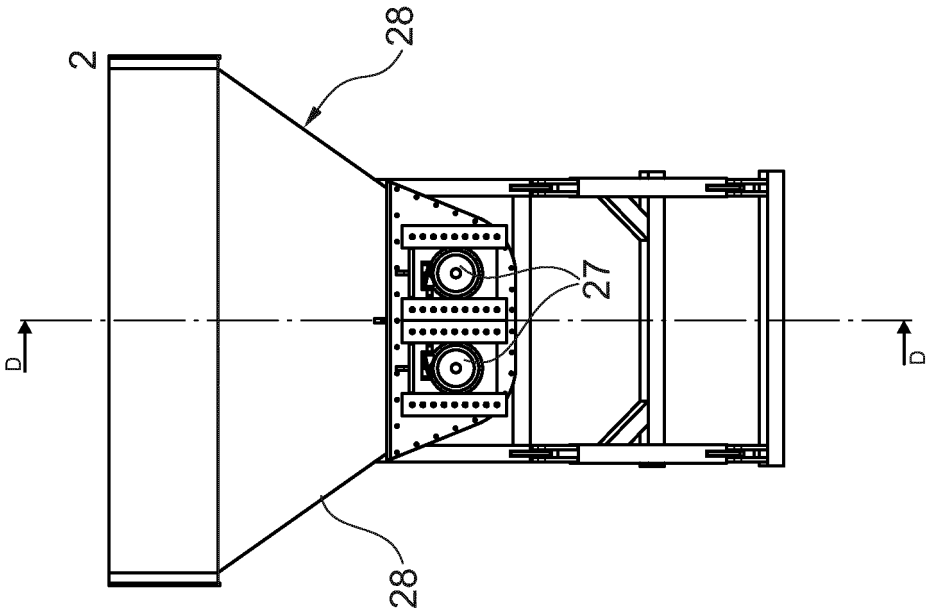


Fig. 3

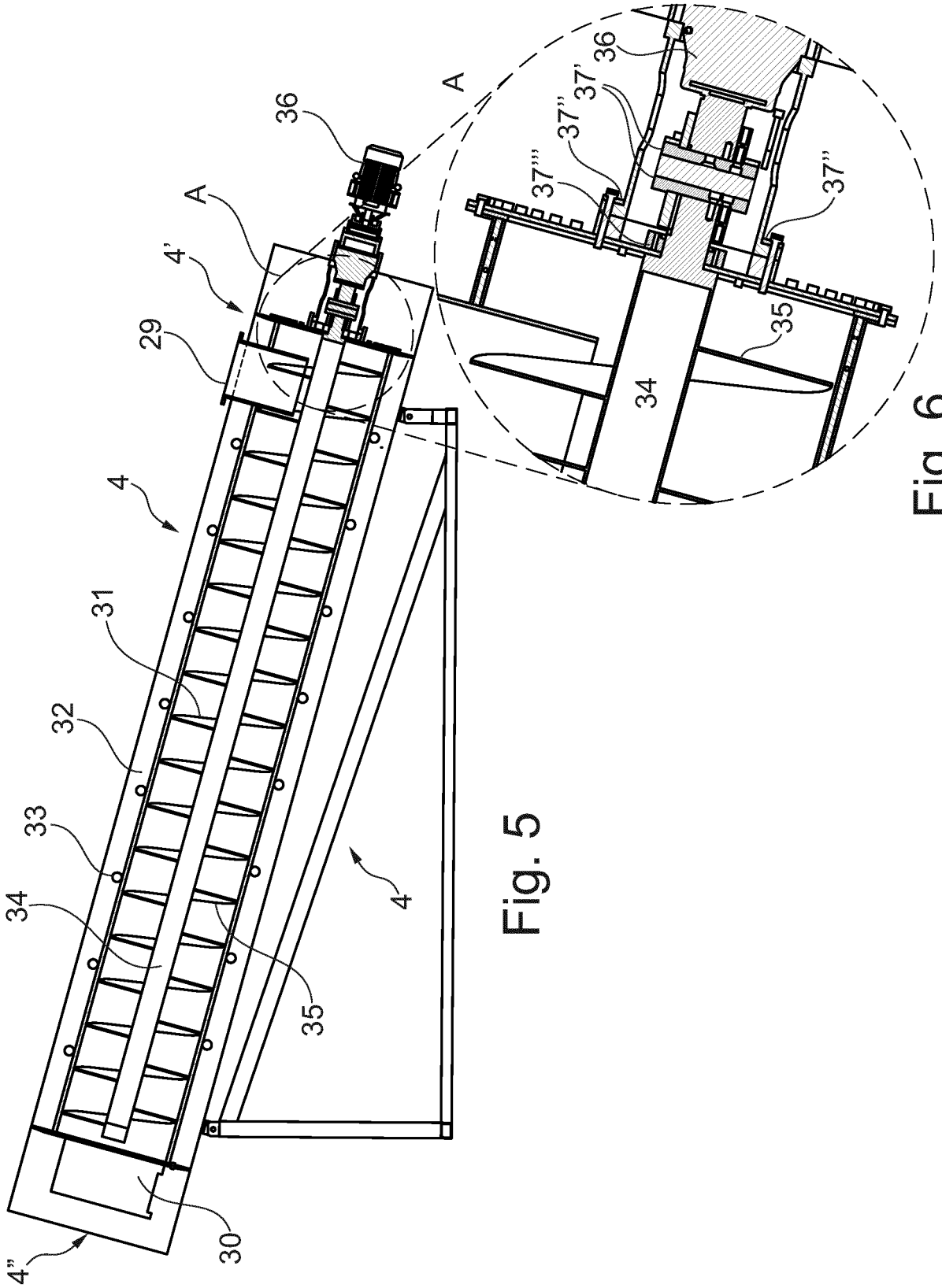


Fig. 5

Fig. 6

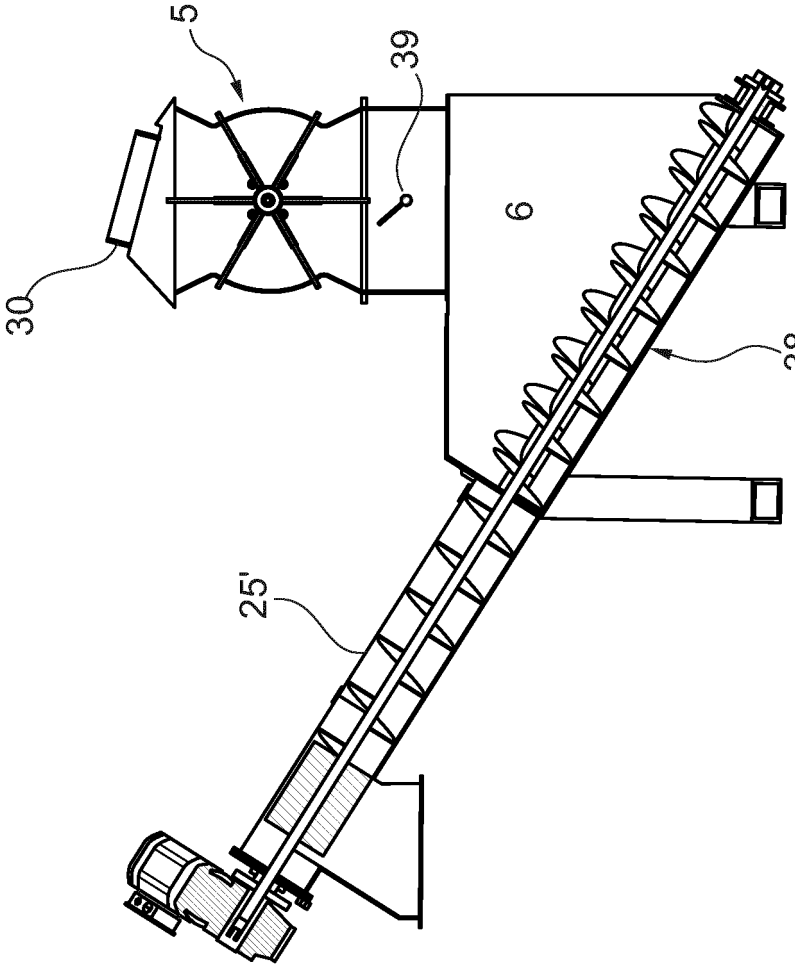


Fig. 8

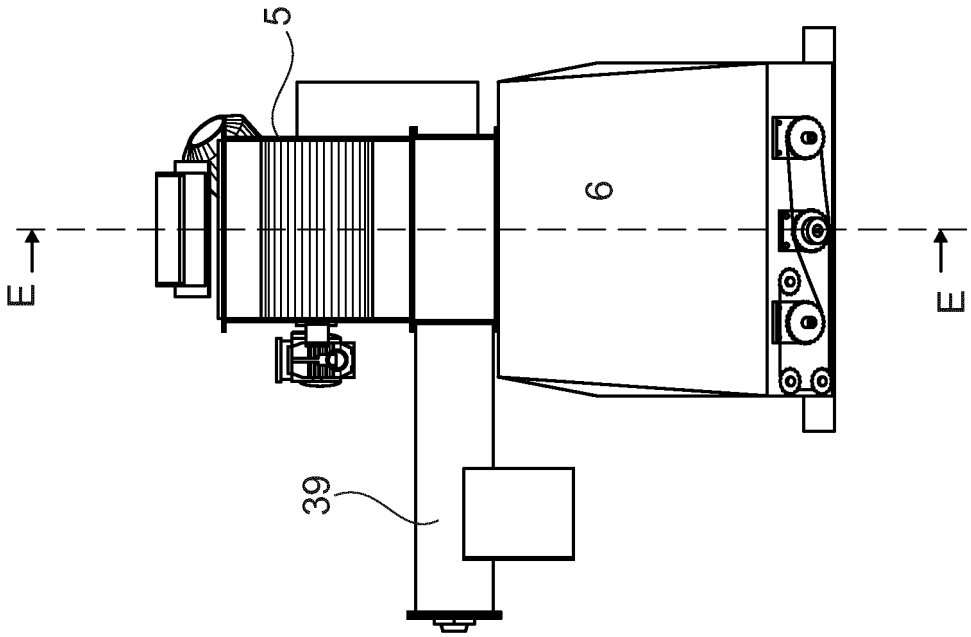


Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 16 17 8225

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Place of search	Date of completion of the search	Examiner
The Hague	29 November 2016	De Meester, Reni

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