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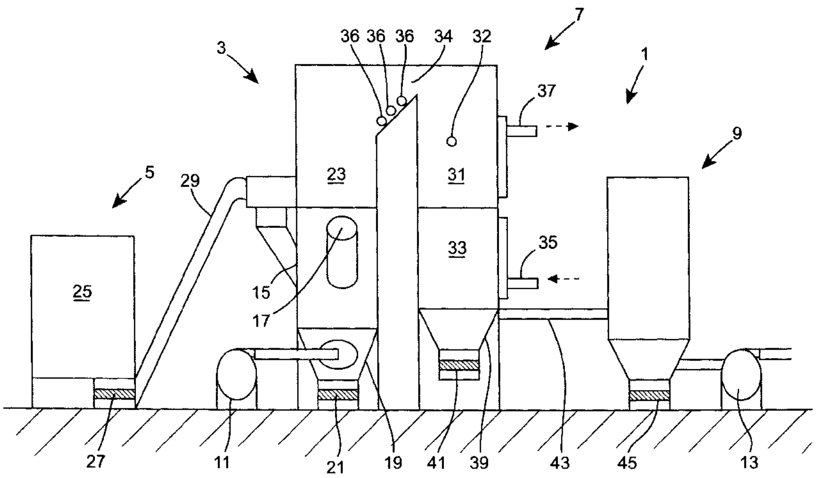

Fig. 1

(57) Abstract: This invention relates to an energy conversion system (1) of the type used in small scale installations producing no more than 0.5Mw electric, 3Mw thermal energy output. The energy conversion system comprises a fluidized bed unit, a by-product fuel feed system, a heat exchanger, an exhaust filter and a negative pressure system. In combination, these provide a compact system capable of use with small amounts of by-product fuel that will adequately treat the by-product fuel so that it does not pose an environmental hazard. The energy conversion system thermally treats by-product and harnesses the heat generated by thermally treating the by-product. The harnessed heat may be used to produce steam or electricity and the heat, steam or electricity can be used in the operation of the installation thereby reducing the overhead operation costs of the small scale installation.

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"An Energy Conversion System"

Introduction

This invention relates to an energy conversion system. In particular, the present invention relates to an energy conversion system that thermally treats by-product and harnesses the heat generated from thermally treating the by-product.

In many processes, a by-product is created that has little or no resale value. It is important to dispose of this by-product in as cost effective and efficient manner as possible. One way in which the by-product may be disposed of is to thermally treat the by-product. However, thermal treatment of by-product is often restricted by law due to unsatisfactory treatment of pathogens in the by-product. Furthermore, certain by-products are expensive and difficult to process.

One example of such a process is a poultry rearing process. The poultry create a significant amount of litter which is typically quite moist. Heretofore, any attempt to thermally treat the litter has required transport of the litter to specialist treatment plants where the litter may be incinerated in specially adapted furnaces. Usually, there is a cost to the farmer to remove the litter from the premises. This is an unpredictable expense to the farmer. Accordingly, the known processes are not economically viable and are not environmentally sustainable.

Another example of such a process is a mushroom production process. After growing mushrooms, a mushroom compost by-product is created which is depleted of the necessary minerals required for further successful mushroom growth. The mushroom compost by-product, often referred to as spent mushroom compost, is of little or no use to the farmer and must be disposed of. This spent mushroom compost is often very damp with a water content level of the order of 70% by weight which requires special treatment of the compost before it may be thermally treated. This creates additional expense to dispose of the compost. Numerous other processes, such as those that create meat and bone meal as by-products, straw, wet wood chips, miscanthus, sludge or other animal manures raise similar problems.

Due to the fact that the by-products are difficult to treat adequately, specialised energy conversion systems are required for the task. These systems are large, cumbersome and expensive and are found in specialist incineration plants. As well as being paid to handle the by-product, the operator of the incineration plant is also able to harness the energy from the by-product and whatever value there is in the by-product is lost to the farmer or producer.

It is an object of the invention to provide an energy conversion system that overcomes at least some of these problems and allows a producer to dispose of the by-products in an efficient and cost effective manner. It is a further object of the invention to allow a producer to harness any value from the by-product.

Statements of Invention

According to the invention there is provided an energy conversion system comprising:-

a fluidised bed unit;

a by-product fuel feed system feeding the fluidised bed unit;

a heat exchanger operatively coupled to the fluidised bed unit;

an exhaust filter operatively coupled to the heat exchanger; and

a negative pressure system operable to maintain a flow of exhaust gases in the direction from the fluidised bed unit through the heat exchanger.

By having such an energy conversion system, it will be possible for the producer to thermally treat a number of by-products and convert the energy in the by-product into heat or electricity. The system is compact, simple to install and operate and therefore may be installed on site. In this way, the by-product will not have to be transported elsewhere at considerable expense but rather may be used on site to reduce costs of the producer.

Furthermore, the system is able to handle various different types of by-product having different characteristics, for example, poultry litter, mushroom compost as well as meat and bone meal from a meat processing facility. As the by-product does not have to be processed and is readily available, the energy conversion system is very cost effective to operate. Preferably, the energy in the by-product is converted into heat and the heat is used advantageously in the process that generates the by-product. The producer will no longer have to pay for disposal of their by-products but rather will be able to benefit from the heat generated by thermally treating their by-products and using that heat in their process. In addition to producing heat, the energy in the by-product may be converted into steam or electricity, both of which can be put to good use.

In addition to the above, the construction of the energy conversion system is such that it has few parts and will be relatively simple to control remotely if desired with the minimum amount of maintenance required. By providing such a simple construction, it is possible for the energy conversion system to be operated as a standalone system in a small installation such as a farm, processing plant or slaughterhouse.

The energy conversion system according to the present invention is suitable for small scale installations, those having a power output of under 3 megawatt (Mw) thermal or 0.5 megawatt (Mw) electrical energy. It will be understood that the present invention does not concern large scale power plants and the like. By providing an energy conversion system with a fluidized bed unit according to the invention, it will be possible to thermally treat the by-product at a temperature of greater than 850°C for a minimum of 2 seconds. The system is able to control small amounts of fuel in a small combustion chamber, the combustion chamber having a size of no more than approximately 2 to 3 cubic metres.

In one embodiment of the invention the fluidised bed unit comprises:

a furnace sump containing fluidised bed media;

an air introducer assembly mounted substantially in the furnace sump; and

a clinker extraction unit for removal of clinkers from the fluidised bed media in the furnace sump.

This is seen as a particularly compact arrangement that will be suitable for use in small installations. The air introducer can maintain the fluidized bed bubbling while at the same time not blow the sand out of the system. Furthermore, by having such an arrangement, the clinkers can be removed with ease thereby providing a system that is relatively maintenance free and efficient.

In one embodiment of the invention the air introducer assembly comprises an air box and a plurality of nozzles supplied by the air box.

In one embodiment of the invention each of the nozzles is mounted on an upstanding sparge pipe.

In one embodiment of the invention the nozzles are evenly spaced about the fluidised bed.

In one embodiment of the invention there are provided a pair of air boxes, each having a plurality of nozzles supplied by their respective air box.

In one embodiment of the invention the air box is mounted internal the furnace sump.

In one embodiment of the invention the air introducer assembly comprises a forced draught fan forcing air into the air introducer assembly.

In one embodiment of the invention the forced draught fan has an air intake connected to one end of an air supply conduit, the other end of the air supply conduit being mounted adjacent the top of the fluidised bed unit.

In one embodiment of the invention the clinker extraction unit comprises a furnace ash removal auger located at the bottom of the furnace sump.

In one embodiment of the invention the furnace sump tapers inwardly towards the bottom of the sump.

In one embodiment of the invention the fluidised bed unit further comprises a diesel burner.

In one embodiment of the invention the fluidised bed unit is provided with a pressure sensor.

In one embodiment of the invention the fluidised bed unit is provided with a plurality of temperature sensors arranged at different heights inside the fluidised bed unit, at least one of which is located in the fluidised bed media, at least one of which is located just above the fluidised bed media in a lower freeboard of the fluidised bed and at least one of which is located adjacent the top of the fluidised bed unit in an upper freeboard of the fluidised bed unit.

In one embodiment of the invention the by-product fuel feed system comprises:

a hopper;

a variable speed auger; and

a fuel conveyor to deliver fuel from the hopper to a charging inlet of the fluidised bed unit.

In one embodiment of the invention the variable speed auger is mounted adjacent the charging inlet of the fluidised bed unit.

In one embodiment of the invention there is provided a further fuel hopper auger mounted at one end of the hopper which feeds fuel from the hopper out through a discharge outlet onto the fuel conveyor.

In one embodiment of the invention the variable speed auger is mounted at one end of the hopper and feeds fuel from the hopper out through a discharge outlet onto the fuel conveyor.

In one embodiment of the invention the fuel conveyor is a chain drive conveyor.

In one embodiment of the invention the fuel conveyor is housed in a sealed casing.

In one embodiment of the invention the hopper comprises a plurality of transverse ribs mounted on the internal base of the hopper, a plurality of the ribs are stationary ribs and a plurality of the ribs are moving ribs, and an actuator to cause reciprocal movement of the moving ribs backwards and forwards in the hopper.

In one embodiment of the invention the heat exchanger comprises:

a heat exchanger unit having a plurality of tubes mounted on an end plate.

In one embodiment of the invention each of the tubes is U-shaped and each end of the tubes is mounted on the end plate.

In one embodiment of the invention there is provided a pair of heat exchanger units coupled to each other and the pair of heat exchanger units are mounted in the heat exchanger, one above the other, and a heating fluid is delivered into the lower heat exchanger unit and allowed to pass through the lower heat exchanger unit to the upper heat exchanger unit and the heated heating fluid is drawn from the upper heat exchanger unit.

In one embodiment of the invention there is a liquid in the tubes.

In one embodiment of the invention the liquid is water and there is provided a water tank to supply water to the heat exchanger units.

In one embodiment of the invention the heat exchanger is operatively coupled to an electricity generation unit.

In one embodiment of the invention the heat exchanger is operatively coupled to a heating system. In one embodiment, the exhaust gases are provided to an electricity generation system. Alternatively, the exhaust gases are fed to a steam boiler to generate steam.

In one embodiment of the invention the heating system is an agricultural growing environment heating system.

In one embodiment of the invention the heating system is an animal shed heating system.

In one embodiment of the invention the heating system comprises a radiator bank.

In one embodiment of the invention the heating system comprises a circulating fan directing hot air from the radiator bank to the interior of an animal shed.

In one embodiment of the invention the animal shed houses poultry.

In one embodiment of the invention there is provided a heat exchanger soot blower.

In one embodiment of the invention the heat exchanger soot blower is mounted in the upper heat exchanger unit between the tubes and the heat exchanger soot blower comprises a rotating pipe having a plurality of venting apertures arranged along the pipe's length.

In one embodiment of the invention the heat exchanger is operatively coupled to the fluidised bed unit by way of a freeboard interconnector.

In one embodiment of the invention there are provided a plurality of freeboard soot blowers.

In one embodiment of the invention there is provided a heat exchanger sump at the bottom of the heat exchanger and a heat exchanger ash removal auger operable to remove ash from the heat exchanger sump.

In one embodiment of the invention the exhaust filter comprises an ash extractor auger.

In one embodiment of the invention the negative pressure system comprises a forced draught fan and an induction draught fan.

In one embodiment of the invention the forced draught fan operates as the forced draught fan of the air introducer assembly forcing air through the fluidised bed.

In one embodiment of the invention the negative pressure system is operable to maintain a pressure of the order of -0.5 mbar to -1.0 mbar between the fluidized bed and the heat exchanger.

In one embodiment of the invention ash and clinkers removed from the fluidised bed are recycled by crushing the ash and clinkers to a suitable particle size and reintroducing the ash and crushed clinkers to the fluidised bed.

In one embodiment of the invention there is provided a fuel drying unit comprising a rotating drum.

In one embodiment of the invention the rotating drum comprises an exhaust gas inlet fed from the exhaust gases of the fluidised bed unit.

Detailed Description of the Invention

The invention will now be more clearly understood from the following description of some embodiments thereof given by way of example only with reference to the accompanying drawings, in which:-

> Figure 1 is a diagrammatic representation of a first embodiment of an energy conversion system according to the present invention;
>
> Figure 2 is a partial front perspective view of the energy conversion system shown in Figure 1;
>
> Figure 3 is a partial rear perspective view of the energy conversion system shown in Figure 1;

Figure 4 is a partial rear perspective view of an alternative configuration of energy conversion system;

Figure 5 is a front perspective view of the fluidised bed;

Figure 6 is a perspective view of the fluidised bed shown from below;

Figure 7 is a front view of the fluidised bed;

Figure 8 is a top plan view of the fluidised bed;

Figure 9 is a top plan view of an alternative embodiment of fluidised bed;

Figure 10 is a front view of the fluidised bed shown in Figure 9;

Figure 11 is a front perspective view of the fluidised bed unit furnace;

Figure 12 is a rear perspective view of the fluidised bed unit furnace;

Figure 13 is a front perspective view of part of the fluidised bed unit furnace;

Figure 14 is a front perspective view of another part of the fluidised bed unit furnace;

Figure 15 is a front perspective view of another still part of the fluidised bed unit furnace;

Figure 16 is a front perspective view of part of the heat exchanger;

Figure 17 is a front perspective view of another part of the heat exchanger;

Figure 18 is a front perspective view of another still part of the heat exchanger;

Figure 19 is a perspective view of the part of the fluidised bed unit furnace shown in Figure 15 connected to the part of the heat exchanger shown in Figure 18;

Figure 20 is a perspective view of the heating tubes of the heat exchanger;

Figure 21 is a side view of the heating tubes shown in Figure 20;

Figure 22 is a top view of the heating tubes shown in Figure 20;

Figure 23 is a front view of the heating tubes shown in Figure 20;

Figure 24 is a perspective view of a heating tube of the heat exchanger;

Figure 25 is a perspective view of a mounting plate of the heat exchanger;

Figure 26 is a perspective view of the heat exchanger casting;

Figure 27 is a front view of the heat exchanger casting;

Figure 28 is a front view of the heat exchanger soot blower;

Figure 29 is a perspective view of a variable speed auger;

Figure 30 is a side view of an auger for use in the variable speed auger;

Figure 31 is an exploded view of part of the fuel conveyor;

Figure 32 is a plan view of an alternative embodiment of a energy conversion system according to the invention; and

Figure 33 is a diagrammatic representation of a steam kit for use with the energy conversion system.

Referring to the drawings and initially to Figure 1 thereof, there is shown an energy conversion system, indicated generally by the reference numeral 1, comprising a fluidised bed unit 3, a by-product fuel feed system 5 feeding the fluidised bed unit 3, a heat exchanger 7 operatively coupled to the fluidised bed unit 3, an exhaust filter 9 operatively coupled to the heat exchanger 7 and a negative pressure system. The negative pressure system comprises a forced draught fan 11 and an induction draught fan 13 which are operable to maintain a flow of exhaust gases in the direction from the fluidised bed unit 3 through the heat exchanger 7.

The fluidised bed unit 3 further comprises a charging inlet 15 for fuel delivered by the by-product fuel feed system 5, a diesel burner (not shown) connected to a burner inlet 17 and a furnace sump 19 containing fluidised bed media. The furnace sump 19 tapers inwardly towards the bottom of the furnace sump where there is a clinker extraction unit, in this case a furnace ash removal auger 21 located at the bottom of the furnace sump 19. The fluidised bed unit further comprises an air introducer assembly most of which is mounted substantially in the furnace sump for delivering air up through the fluidised bed media in the sump. The air introducer further comprises the forced draught fan 11 from the negative pressure system. Above the furnace sump 19 is the furnace freeboard 23.

The by-product fuel feed system 5 comprises a hopper 25, a variable speed auger 27 and a fuel conveyor 29 to deliver fuel from the hopper to the charging inlet 15 of the fluidised bed unit. The variable speed auger 27 is operated to deliver a desired amount of fuel from the hopper 25 onto the fuel conveyor 29.

The heat exchanger 7 comprises a pair of heat exchanger units, an upper heat exchanger unit 31 and a lower heat exchanger unit 33. The lower heat exchanger unit 33 is provided with a cold water flow pipe 35 and the upper heat exchanger unit 31 is provided with a hot water return pipe 37. The upper heat exchanger unit 31 further comprises a heat exchanger soot blower 32 mounted across the heat exchanger and extending between a plurality of tubes (not shown) of the upper heat exchanger unit. The heat exchanger soot blower 32 is rotatably mounted on the upper heat exchanger unit 31. Below the lower heat exchanger unit 33 is a heat exchanger sump 39 which is provided with a heat exchanger ash removal auger 41 to remove ash from the heat exchanger sump. The heat exchanger 7 is operatively coupled to the fluidised bed unit by way of a freeboard interconnector 34. The freeboard interconnector 34 is provided with a plurality of pulsed blower nozzles 36 arranged substantially in line with the floor of the freeboard interconnector 34. Pressurised air is periodically passed through the pulsed blower nozzles 36 to dislodge any settled ash from the floor of the freeboard interconnector 34. A heat exchanger exhaust conduit 43 operatively couples the heat exchanger 7 to the exhaust filter 9.

The exhaust filter 9 is a bag filter having a plurality of bags to catch the fly ash from the exhaust gases. The exhaust filter 9 comprises an ash extractor auger 45 located at the bottom of the exhaust filter 9. The induction draught fan 13 is coupled to the exhaust filter 9 and draws exhaust gases through the energy conversion system from the fluidised bed unit 3, through the heat exchanger 7 and through the exhaust filter 9.

In use, a by-product fuel is delivered from the hopper 25 along the fuel conveyor 29 and is delivered into the fluidised bed unit 3 where it is burnt at a temperature of at least 850˚C for at least two seconds. The temperature of the fluidised bed is between 610˚C and 750˚C, preferably approximately 670˚C. Just above the fluidised bed, in the lower furnace freeboard, the temperature is approximately 850˚C and at the top of the upper furnace freeboard adjacent the freeboard interconnector 34, the temperature is in the region of between 850˚C and 1200˚C. The height of the furnace freeboard and the negative pressure is such that the fuel remains in the region at or above 850˚C for a minimum of 2 seconds and this ensures that all pathogens are killed.

A plurality of temperature sensors are arranged in the fluidised bed unit furnace. There are four temperature sensors in the fluidised bed itself, one temperature sensor in the lower furnace freeboard just above the fluidised bed and another temperature sensor in the upper furnace freeboard. These temperature sensors closely monitor the temperature of the fluidised bed unit and if the temperature should deviate from the desired values or ranges, corrective action may be taken. If the temperature of the fluidised bed lowers, the variable speed augers are operated to increase the amount of fuel that is delivered to the fluidised bed unit 3. If the fuel has a relatively high moisture content, the fuel may not immediately cause the temperature to rise in the fluidised bed and other action must be taken. In such an instance, further fuel may be added or alternatively, the diesel burner is started and provides a boost to the fluidised bed.

The hot exhaust gases rise up through the furnace through the lower and upper furnace freeboards, through the interconnecting freeboard 34 and down through the heat exchanger 7. The heat exchanger 7 comprises a plurality of tubes (not shown) filled with water and the water in the tubes is heated by the hot exhaust gases passing over the tubes. The hot exhaust gases are then passed out of the heat exchanger to the exhaust filter 9 where fly ash is removed from the exhaust gases and the filtered exhaust gases are released into the atmosphere. The exhaust gases released into the atmosphere are still at approximately 150˚C to 200˚C. An exhaust filter has an ash extractor auger 45 which removes ash out from the filter. The ash taken from the filter typically has a phosphorous content of 18% by weight of the ash and 8% potassium by weight of the ash and may be sold on as a useful by-product for fertilizers and the like.

The heat exchanger 7 may also be coupled to a heating system (not shown) which comprises a radiator bank and at least one fan for circulating hot air surrounding the fan. In order to couple the heat exchanger to the heating system, the hot water return pipe 37 is connected to the radiator bank and the cold water flow pipe 35 is connected to a water source such as a water buffer tank or a return from the radiator bank. If a water buffer tank is used the water filling the water buffer tank may come from the radiator bank. The heating system is preferably for an animal housing such as a poultry housing however the present invention could be used as a heating system with other types of animals, agricultural processes such as mushroom growing or domestic heating systems.

Referring to Figures 2 and 3, there are shown partial perspective views of the energy conversion system according to the present invention where like parts have been given the same reference numerals as before. The energy conversion system’s by-product fuel feed system comprises a variable speed auger 27 located adjacent to the hopper (not shown). The variable speed auger 27 is operable to deliver the desired amount of fuel from the hopper onto the fuel conveyor 29, which in turn comprises a chain drive conveyor in a sealed casing. The casing is sealed to prevent ingress of air into the system. The fuel conveyor terminates in a fuel conveyor outlet casing 47 which is mounted just above the fuel chute 49 leading to the charging inlet 15 of the fluidised bed unit 3. A connecting conduit that is usually located between the fuel conveyor outlet casing and the fuel chute has been removed for clarity. By having the fuel conveyor outlet casing and the fuel chute separated in this manner, there is room to provide a fluidised bed media dosing assembly (not shown) to dose the fluidised bed unit as and when required. Furthermore, the fuel chute is angled to ensure fuel slides easily into the bed.

The furnace sump has a pair of apertures 51, 53. The aperture 51 is to allow through passage of air into an air box (not shown) of an air introducer assembly of the fluidised bed unit. The aperture 53 is to allow insertion of the furnace ash removal auger. Referring specifically to Figure 3, there is shown an access/viewing hatch 55 for the fluidised bed unit 3 and an exhaust outlet 57 from the heat exchanger that delivers the exhaust gas to the exhaust filter (not shown).

Referring to Figure 4, there is shown an alternative construction of energy conversion system according to the present invention. The exhaust filter 9 is located to the rear of the heat exchanger 7. In this configuration, the energy conversion system has a compact footprint without degrading the performance of the energy conversion system. Furthermore, in the embodiments shown, the fuel conveyor 29 has been substantially in line with the fluidised bed unit and the heat exchanger but in some cases it is preferable to have the conveyor arranged orthogonal to the arrangement of fluidised bed unit and heat exchanger and the fuel hopper arranged to provide a compact footprint to the energy conversion system.

Referring to Figures 5 to 8 inclusive, there are shown various views of the fluidised bed air introducer assembly, indicated generally by the reference numeral 60, mounted in the furnace sump 19, where like parts have been given the same reference numerals as before. The air introducer assembly 60 comprises an air box 61 having a plurality of upstanding sparge pipes 63 protruding upwardly and outwardly therefrom. The sparge pipes 63 each have a venting nozzle at their end distal from the air box. An end cap 65 is placed over the free end of each of the sparge pipes to prevent ingress of fluidising bed media into the sparge pipes 63 and yet allow discharge of air from the nozzle into the fluidising bed media (not shown). The nozzles are spread evenly about the fluidised bed to provide uniform discharge of air into the fluidised bed. The furnace sump 19 is wedge shaped so that clinkers that form in the fluidised bed media will travel towards the bottom of the furnace sump to the furnace ash removal auger (not shown) housed in the aperture 53. In this way, clinkers and ash can be effectively removed from the bottom of the fluidised bed so that they do not hinder performance of the fluidised bed.

Referring to Figures 9 and 10, there is shown an alternative embodiment of fluidised bed air introducer assembly, indicated generally by the reference numeral 70, mounted in a furnace sump 19 for use in an energy conversion system according to the present invention, where like parts have been given the same reference numeral as before. The air introducer assembly comprises a pair of air boxes 67, 69, each having a plurality of upstanding sparge pipes 63 protruding upwardly and outwardly therefrom. The sparge pipes 63 each have a venting nozzle at their end distal from the air box 67, 69. An end cap 65 is placed over the free end of each of the sparge pipes to prevent ingress of fluidising bed media into the sparge pipes 63 and yet allow discharge of air from the nozzle into the fluidising bed media (not shown). The nozzles are spread evenly about the fluidised bed to provide uniform discharge of air into the fluidised bed.

Referring to Figures 11 to 15, there are shown detailed views of parts of the fluidised bed unit 3. Referring specifically to Figures 11 and 12, there is shown parts of the fluidised bed furnace 71 that sit directly above the furnace sump 19. These comprise a lower furnace casing 73 which comprises the charging inlet 15, the burner inlet 17, the fuel chute 49 leading to the charging inlet 15 and the access hatch 55. Mounted above the lower furnace casing 73 (Figure 13) is an intermediate furnace casing 75 (Figure 14) which has a plurality of access points 77 for temperature probes and/or air introducer nozzles. The lower furnace casing and the intermediate furnace casing house the lower freeboard of the fluidised bed unit. Referring specifically to Figure 15, there is shown an upper furnace casing 78 that sits on top of the intermediate furnace casing 75. The upper furnace casing 78 houses the upper freeboard of the fluidised bed and defines an exhaust gas outlet 79 for through passage of exhaust gases into the heat exchanger (not shown).

Referring to Figures 16 to 18 inclusive, there are shown detailed views of parts of the heat exchanger 7. Referring specifically to Figure 16, there is shown a perspective view of the lower heat exchanger unit 33 mounted on a frame 81. The lower heat exchanger has an aperture 83 in one side thereof for reception of a mounting plate (not shown) having a plurality of heating tubes thereon. Referring now to Figure 17 there is shown a perspective view of the upper heat exchanger unit 31. The upper heat exchanger unit 31 also has an aperture 83 for reception of a mounting plate (not shown) having a plurality of heating tubes thereon. The construction of the upper and lower heat exchanger units 31, 33 (excluding the frame 81) is identical which simplifies manufacture and installation. Referring to Figure 18, there is shown a heat exchanger freeboard 85 having an opening 87 for fluid communication with the exhaust gas outlet 79 of the upper freeboard casing 78.

Referring to Figure 19, there is shown a perspective view of the upper freeboard casing 78 connected to the heat exchanger freeboard 85 and together they form the freeboard interconnector 34, the passageway for exhaust gases from the fluidised bed unit 3 to the heat exchanger 7.

Referring to Figures 20 to 28, there are shown various views of parts of the heat exchanger units 31, 33. Referring first of all to Figures 20 to 23 inclusive, there are shown various views of the heat exchanger tubes 91 mounted on a mounting plate 93. The ends of the tubes protrude through the mounting plate (Figures 21, 22) so that water or other liquid may be passed through one end of the tube and returned out the other end of the tube after being heated by the hot exhaust gases. A heat exchanger soot blower (Figure 28) comprising a pipe 95 having a plurality of apertures 97 along its length is mounted intermediate a pair of rows of heat exchanger tubes across the width of the mounting plate 93 so that as it rotates and compressed air is forced out of the apertures 97 in the pipe 95, ash will be removed from the tubes. In the present embodiment, the heat exchanger soot blower pipe is mounted in the upper heat exchanger unit only and it is not necessary to put a heat exchanger soot blower pipe in the lower heat exchanger unit. It is envisaged that the soot blower will be operated for one minute in every thirty minutes to prevent ash build up.

Referring to Figure 24 there is shown an enlarged view of a heat exchanger tube. The heat exchanger tube 91 comprises a pair of substantially straight sections 99, 101, and an arcuate section 103 bridging the straight sections. Referring to Figure 25, there is shown an enlarged view of the mounting plate 93 which comprises a plurality of apertures 105 each of which is dimensioned to receive the end of a heat exchanger tube therein and allow the end of the heat exchanger tube to pass therethrough. Once the end of the heat exchanger tube has passed through the mounting plate, the tube is welded in position so that a small portion of the tube protrudes through the mounting plate 93.

Referring now to Figures 26 and 27, there is shown a number of views of the heat exchanger casting 107. The mounting plate (not shown) is mounted directly onto the heat exchanger casting 107. The heat exchanger casting 107 comprises a plurality of defined channels 109(a)-(h) therein. The ends of the tubes 91 that protrude through the mounting plate 93 correspond with the channels 109(a)-(h) so that the end of one tube engages one channel and the other end of that tube engages the next adjacent channel. This is repeated for all the rows of tubes so that the two outermost channels 109(a) and 109(h) will have the ends of one row of tubes therein whereas all other channels 109(b)-(g) will have the ends of two rows of tubes therein. The tubes 91 and channels 109(a)-(h) are arranged to provide a labyrinthine passageway for the liquid through the heat exchanger unit.

In use, water is delivered into one channel 109(a) adjacent the end of the plate. This water travels out of the channel 109(a) through the tubes 91 whose ends are in that channel 109(a), flows through those tubes 91 and returns into the next channel 109(b). The water in channel 109(b) flows out of the channel through the tubes 91 in channel 109(b) whose second end is in communication with channel 109(c). When the water reaches channel 109(c) it flows out of the channel 109(c) through the tubes 91 in channel 109(c) whose second end is in communication with channel 109(d). This is repeated until the water has worked its way from the channel 109(a) through the intervening channels 109(b) – (g) to the channel 109(h). As the water passes through the tubes, it is heated by the exhaust gases.

When the water in the lower heat exchanger unit 33 reaches the last channel 109(h), an interconnector pipe delivers water from the channel 109(h) to the channel 109(a) in the upper heat exchanger and the water follows a similar path in upper heat exchanger to that described above. When the water reaches the channel 109(h) in the upper heat exchanger, it is drawn off to a radiator unit (not shown) for use in heating applications. Preferably, there is provided a pair of interconnector pipes delivering water from the channel 109(h) of the lower heat exchanger unit to the channel 109(a) of the upper heat exchanger unit and the pair of interconnector pipes is crossed over to provide more uniform heating of the water.

Referring to Figure 29, there is shown a perspective view of a variable speed auger 27. The variable speed auger 27 comprises a discharge outlet 111 through which by-product fuel is delivered by the augers to a conveyor (not shown). A speed controllable motor (not shown) is coupled to the axes 113 of the augers (not shown). Referring to Figure 30, there is shown a side view of one auger 115 for use in the variable speed auger 27 shown in Figure 29. The variable speed auger 27 preferable has two augers 115 mounted side by side and counter-rotating with respect to each other.

Referring to Figure 31, there is shown an exploded view of part of a fuel conveyor 29. The fuel conveyor comprises a closed casing 117 with a removable inspection hatch 119 and a pair of flanged ends 121 for secure connection to another part of a fuel conveyor 29, a discharge outlet of a variable speed auger, an inlet of a variable speed auger (when the variable speed auger is positioned adjacent the fluidised bed unit) or a fuel chute.

Referring to Figure 32, there is shown an alternative embodiment of energy conversion system, indicated generally by the reference numeral 200. The energy conversion system comprises a dryer 251 for drying by-product prior to the by-product being delivered into the fluidized bed unit 237. In this way, relatively moist by-product 235, for example having a moisture content of the order of 70% by weight, can be delivered into the dryer 251 and exhaust gases coming from the energy conversion system can be captured and delivered into the dryer 251 with the by-product. The dryer 251 comprises a rotating drum type dryer that rotates and agitates the by-product and the hot exhaust gases will cause the by-product to dry out. In this way, the moisture content of the by-product can be reduced significantly, for example to the order of 40% by weight moisture content, before the by-product is delivered into the fluidized bed. This will allow for better control of the energy conversion system and in particular this will allow the fluidised bed to operate in a relatively uniform manner. This is seen as a particularly useful arrangement for use with spent mushroom compost.

The energy conversion system 200, is partially separated from a fuel storage area 207 by a dividing wall 231 which projects orthogonally from a surrounding wall 233 of a processing site 205. A load 235 of spent mushroom compost is located within the fuel storage area 207. The energy conversion system 200 comprises a combustion apparatus in the form of a first fluidised bed unit 237, a by-product fuel feed system indicated generally by the reference numeral 239 feeding the first fluidised bed unit 237, a pair of primary heat exchangers 241 operatively coupled to the first fluidised bed unit 237, an air-air heat exchanger 243, an ash filter 245, and exhaust filter 247 and a negative pressure system. The negative pressure system comprises a forced draught fan 248 connected, by way of an air pipe (not shown), to the first fluidised bed unit 237 and an induction draught fan 249 mounted on the exhaust filter 247 which are operable to maintain a flow of exhaust gases in the direction from the first fluidised bed unit 237 through the primary heat exchangers 241 and onwards.

The by-product fuel feed system 239 comprises a wet fuel hopper 250, a rotary drum dryer 251 and a dry fuel hopper 253. The wet fuel hopper 250 is fitted with a first variable speed auger 255 which supplies the spent mushroom compost fuel onto a first fuel conveyor 257 to deliver the spent mushroom compost by-product fuel exiting the wet fuel hopper 250 to the rotary drum dryer 251. The rotary drum dryer 251 comprises three rotating drums (not shown) arranged on an incline such that wet fuel entering will be discharged as dry fuel at the opposite end thereof. The by-product fuel feed system 239 comprises a second fuel conveyor 259 for conveying the spent mushroom compost fuel from the rotary drum dryer 251 to the dry fuel hopper 253. Finally the dry fuel hopper 253 comprises a second variable speed auger 261 for conveying spent mushroom compost fuel onto a main fuel conveyor 263. The main fuel conveyor 263 conveys fuel to a fuel metering unit 265 which is in turn connected to a fuel charging inlet (not shown) on the first fluidised bed unit 237. The fuel metering unit 265 comprises twin, counter-rotating augers (not shown) for accurately controlling the fuel that is fed into the first fluidised bed unit 237, such that the combustion temperature therein may be accurately controlled. The rotary drum drier is supplied with heated gases via a gas inlet 267 and has an exhaust gas outlet 269 which is vented through a filtering system 361 outside the spent mushroom compost processing site 205. The by-product fuel feed system 239 further comprises a second fluidised bed unit 271, which may be of a smaller size to the first fluidised bed unit 237. The second fluidised bed unit 271 receives fuel from a dryer fuel conveyor 273 which branches off from the main fuel conveyor 263. The spent mushroom compost fuel is fed to a fuel metering unit (not shown) similar to the fuel metering unit 265 connected to the first fluidised bed unit 237. The heated exhaust gases generated by the second fluidised bed unit 271 are fed into the rotary drum dryer 251 by way of the gas inlet 267. The second fluidised bed unit 271 produces exhaust gases having a temperature in the range 800 – 900 °C for drying the spent mushroom compost fuel. In this way, the by-product fuel, in this case spent mushroom compost, is used to provide energy to dry the by-product fuel itself.

Exhaust gases generated by the combustion of spent mushroom compost by-product fuel within the first fluidised bed unit 237 are passed through the pair of primary heat exchangers 241, and from there the air-air heat exchanger 243. Thereafter the exhaust gases pass through the ash-cyclone 245, which allows ash to collect therein and finally the exhaust gases are passed through the exhaust filter 247, generally a bag filter. Exhaust gases from the exhaust filter 247 are sufficiently cooled and clean to be released to the atmosphere.

The heat exchangers 241 are connected to a piping network comprising a hot-water pipe 275 and a cold water pipe 277 which are connected to a buffer tank 279, from which the water supplies for the mushroom production site are drawn. The main flow line 211 and main return line 213 for supplying heated water, and returning cooled water to and from the mushroom growing sheds are connected to the buffer tank 279.

The energy conversion system 229 operates to keep the liquid, in this case water, in the buffer tank 279 at a uniform temperature, preferably 85°C. The energy conversion system 229 burns spent mushroom compost and harnesses the heat from the combustion of the spent mushroom compost to heat water which is passed to the buffer tank 279. The hot water in the buffer tank 279 is then delivered to radiator elements (not shown) in sheds (not shown) and returned to the buffer tank 279 where it may then be returned to the energy conversion system 229 for re-heating. Various hydronic manifolds may be provided to ensure that the flow and the return water is kept as separate as possible to prevent thermal siphoning of the heat in the water and to ensure that the hottest water is delivered to the indirect heaters 209 and the coldest water is returned to the spent mushroom compost processing plant 205.

The energy conversion system 229 further comprises an air intake pipe 281 which is mounted on the external walls 233 of the spent mushroom compost processing site. The air intake pipe 281 has an open end located in the fuel storage area 207, ideally above any spent mushroom compost that may be stored there. In this way, the foul air emanating from the load 235 of spent mushroom compost is the source of the air in the air intake pipe 281. The forced draught fan 248 is connected to the other end of the air intake pipe 281, such that the forced draught fan 248 operates on the air taken from the fuel storage area 207. The forced draught fan 248 forces the intake air through the air-air heat exchanger 243 so that the intake air is heated through indirect interaction with the exhaust gases coming from the first fluidised bed unit 237. The forced draught fan 248 forces the intake air through the air-air heat exchanger 243 and from then on to the sump of the first fluidised bed unit 237 to provide the fluidisation of the particles therein. In this way, the fluidising air within the first fluidised bed unit 237 is heated which will provide greater stability in the operation of the first fluidised bed unit 237, thereby making it more energy efficient.

The exhaust filter 247 is a bag filter having a plurality of bags to catch the fly ash from the exhaust gases. The exhaust filter 247 comprises an ash extractor auger (not shown) located at the bottom of the exhaust filter 247. The induction draught fan 249 is coupled to the exhaust filter 247 and draws exhaust gases through the spent mushroom compost processing plant 205 from the first fluidised bed unit 237, through the heat exchangers 241 and through the exhaust filter 247.

Referring to Figure 33, there is shown a steam kit for use with the energy conversion system according to the present invention. The steam kit comprises a steam boiler 360 fed from a fluidized bed unit 337 wherein the exhaust gases pass over a water-in-tube heat exchanger arrangement (not shown) causing the water therein to boil and generate steam. Approximately half of this steam may be supplied to a shed where mushrooms or the like are being grown for use in sterilisation of the shed. The steam, which will be at a temperature of approximately 160°C, is supplied to the shed via steam outflow pipe 362. Water for heating in the steam boiled is supplied thereto by a water supply pipe 364. The steam that is not sent to the mushroom growing shed is sent to a plate heat exchanger 366, which is used to supply hot water to heat the mushroom growing sheds. Steam entering the plate heat exchanger 366 is at approximately 160°C and it will heat the water for the sheds to approximately 90°C. This heated water will then pass to a buffer tank 379 for supply to the shed or in some cases, may be fed directly to the main flow line 311. The cooled steam which was used in the plate heat exchanger 366 to heat the water is now fed to a condensing tank 368 where it is condensed into water again, and subsequently fed back into the steam boiler. The exhaust gases pass to an air-air heat exchanger 343 from the steam boiler 360 and from there to an ash cyclone 345 before reaching an exhaust filter 347. It can be seen how the steam generation kit may be incorporated with relative ease into an existing system.

By thermal treatment or thermally treating the by-product, what is meant is that the by-product is burnt, incinerated or combusted in the fluidized bed. By combusted, what is meant is a process involving the oxidisation of fuel in order to use the energy thus generated. Reference has been made to the incineration of waste and/or by-products and the terms have been used largely interchangeably throughout the specification. For example, in some jurisdictions, poultry litter or mushroom compost is considered to be a by-product whereas in other jurisdictions it is considered to be a waste.

In this specification the terms “comprise, comprises, comprised and comprising” and the terms “include, includes, included and including” are all deemed totally interchangeable and should be afforded the widest possible interpretation.

The invention is in no way limited to the embodiment hereinbefore described but may be varied in both construction and detail within the scope of the specification.

Claims:

(1) An energy conversion system comprising:-

a fluidised bed unit;

a by-product fuel feed system feeding the fluidised bed unit;

a heat exchanger operatively coupled to the fluidised bed unit;

an exhaust filter operatively coupled to the heat exchanger; and

a negative pressure system operable to maintain a flow of exhaust gases in the direction from the fluidised bed unit through the heat exchanger.

(2) An energy conversion system as claimed in claim 1 in which the fluidised bed unit comprises:

a furnace sump containing fluidised bed media;

an air introducer assembly mounted substantially in the furnace sump; and

a clinker and ash extraction unit for removal of clinkers and ash from the fluidised bed media in the furnace sump.

(3) An energy conversion system as claimed in claim 2 in which the air introducer assembly comprises an air box and a plurality of nozzles supplied by the air box.

(4) An energy conversion system as claimed in claim 3 in which each of the nozzles is mounted on an upstanding sparge pipe.

(5) An energy conversion system as claimed in claim 3 or 4 in which the nozzles are evenly spaced about the fluidised bed.

(6) An energy conversion system as claimed in claims 3 to 5 in which there are provided a pair of air boxes, each having a plurality of nozzles supplied by their respective air box.

(7) An energy conversion system as claimed in claims 3 to 6 in which the air box is mounted internal the furnace sump.

(8) An energy conversion system as claimed in claims 2 to 7 in which the air introducer assembly comprises a forced draught fan forcing air into the air introducer assembly.

(9) An energy conversion system as claimed in claim 8 in which the forced draught fan has an air intake connected to one end of an air supply conduit, the other end of the air supply conduit being mounted adjacent the top of the fluidised bed unit.

(10) An energy conversion system as claimed in claims 2 to 9 in which the clinker and ash extraction unit comprises a furnace ash removal auger located at the bottom of the furnace sump.

(11) An energy conversion system as claimed in claims 2 to 10 in which the furnace sump tapers inwardly towards the bottom of the sump.

(12) An energy conversion system as claimed in any preceding claim in which the fluidised bed unit further comprises a diesel burner.

(13) An energy conversion system as claimed in any preceding claim in which the fluidised bed unit is provided with a pressure sensor.

(14) An energy conversion system as claimed in any preceding claim in which the fluidised bed unit is provided with a plurality of temperature sensors arranged at different heights inside the fluidised bed unit, at least one of which is located in the fluidised bed media, at least one of which is located just above the fluidised bed media in a lower freeboard of the fluidised bed and at least one of which is

located adjacent the top of the fluidised bed unit in an upper freeboard of the fluidised bed unit.

(15) An energy conversion system as claimed in any preceding claim in which the by-product fuel feed system comprises:

a hopper;

a variable speed auger; and

a fuel conveyor to deliver fuel from the hopper to a charging inlet of the fluidised bed unit.

(16) An energy conversion system as claimed in claim 17 in which the variable speed auger is mounted adjacent the charging inlet of the fluidised bed unit.

(17) An energy conversion system as claimed in claim 18 in which there is provided a further fuel hopper auger mounted at one end of the hopper which feeds fuel from the hopper out through a discharge outlet onto the fuel conveyor.

(18) An energy conversion system as claimed in claim 17 in which the variable speed auger is mounted at one end of the hopper and feeds fuel from the hopper out through a discharge outlet onto the fuel conveyor.

(19) An energy conversion system as claimed in claims 15 to 18 in which the fuel conveyor is a chain drive conveyor.

(20) An energy conversion system as claimed in claims 15 to 19 in which the fuel conveyor is housed in a sealed casing.

(21) An energy conversion system as claimed in claims 15 to 20 in which the hopper comprises a plurality of transverse ribs mounted on the internal base of the hopper, a plurality of the ribs are stationary ribs and a plurality of the ribs are

moving ribs, and an actuator to cause reciprocal movement of the moving ribs backwards and forwards in the hopper.

(22) An energy conversion system as claimed in any preceding claim in which the heat exchanger comprises:

a heat exchanger unit having a plurality of tubes mounted on an end plate.

(23) An energy conversion system as claimed in claim 22 in which each of the tubes is U-shaped and each end of the tubes is mounted on the end plate.

(24) An energy conversion system as claimed in claim 22 or 23 in which there is provided a pair of heat exchanger units coupled to each other and the pair of heat exchanger units are mounted in the heat exchanger, one above the other, and a heating fluid is delivered into the lower heat exchanger unit and allowed to pass through the lower heat exchanger unit to the upper heat exchanger unit and the heated heating fluid is drawn from the upper heat exchanger unit.

(25) An energy conversion system as claimed in claim 22 to 24 in which there is a liquid in the tubes.

(26) An energy conversion system as claimed in claim 25 in which the liquid is water and there is provided a water tank to supply water to the heat exchanger units.

(27) An energy conversion system as claimed in any preceding claim in which the heat exchanger is operatively coupled to an electricity generation unit.

(28) An energy conversion system as claimed in any preceding claim in which the heat exchanger is operatively coupled to a heating system.

(29) An energy conversion system as claimed in claim 28 in which the heating system is an agricultural growing environment heating system.

(30) An energy conversion system as claimed in claim 28 in which the heating system is an animal shed heating system.

(31) An energy conversion system as claimed in claim 28 to 30 in which the heating system comprises a radiator bank.

(32) An energy conversion system as claimed in claim 31 in which the heating system comprises a circulating fan directing hot air from the radiator bank to the interior of an animal shed.

(33) An energy conversion system as claimed in claims 30 to 32 in which the animal shed houses poultry.

(34) An energy conversion system as claimed in claims 22 to 33 in which there is provided a heat exchanger soot blower.

(35) An energy conversion system as claimed in claim 34 in which the heat exchanger soot blower is mounted in the upper heat exchanger unit between the tubes and the heat exchanger soot blower comprises a rotating pipe having a plurality of venting apertures arranged along the pipe's length.

(36) An energy conversion system as claimed in any preceding claim in which the heat exchanger is operatively coupled to the fluidised bed unit by way of a freeboard interconnector.

(37) An energy conversion system as claimed in claim 36 in which there are provided a plurality of freeboard soot blowers.

(38) An energy conversion system as claimed in any preceding claim in which there is provided a heat exchanger sump at the bottom of the heat exchanger and a heat exchanger ash removal auger operable to remove ash from the heat exchanger sump.

(39) An energy conversion system as claimed in any preceding claim in which the exhaust filter comprises an ash extractor auger.

(40) An energy conversion system as claimed in any preceding claim in which the negative pressure system comprises a forced draught fan and an induction draught fan.

(41) An energy conversion system as claimed in claim 40 in which the forced draught fan operates as the forced draught fan of the air introducer assembly forcing air through the fluidised bed.

(42) An energy conversion system as claimed in claims 40 or 41 in which the negative pressure system is operable to maintain a pressure of the order of -0.5 mbar to -1.0 mbar between the fluidised bed and the heat exchanger.

(43) An energy conversion system as claimed in claim 2 in which ash and clinkers removed from the fluidised bed are recycled by crushing the ash and clinkers to a suitable particle size and reintroducing the ash and crushed clinkers to the fluidised bed.

(44) An energy conversion system as claimed in any preceding claim in which there is provided a fuel drying unit comprising a rotating drum.

(45) An energy conversion system as claimed in claim 44 in which the rotating drum comprises an exhaust gas inlet fed from the exhaust gases of the fluidised bed unit.

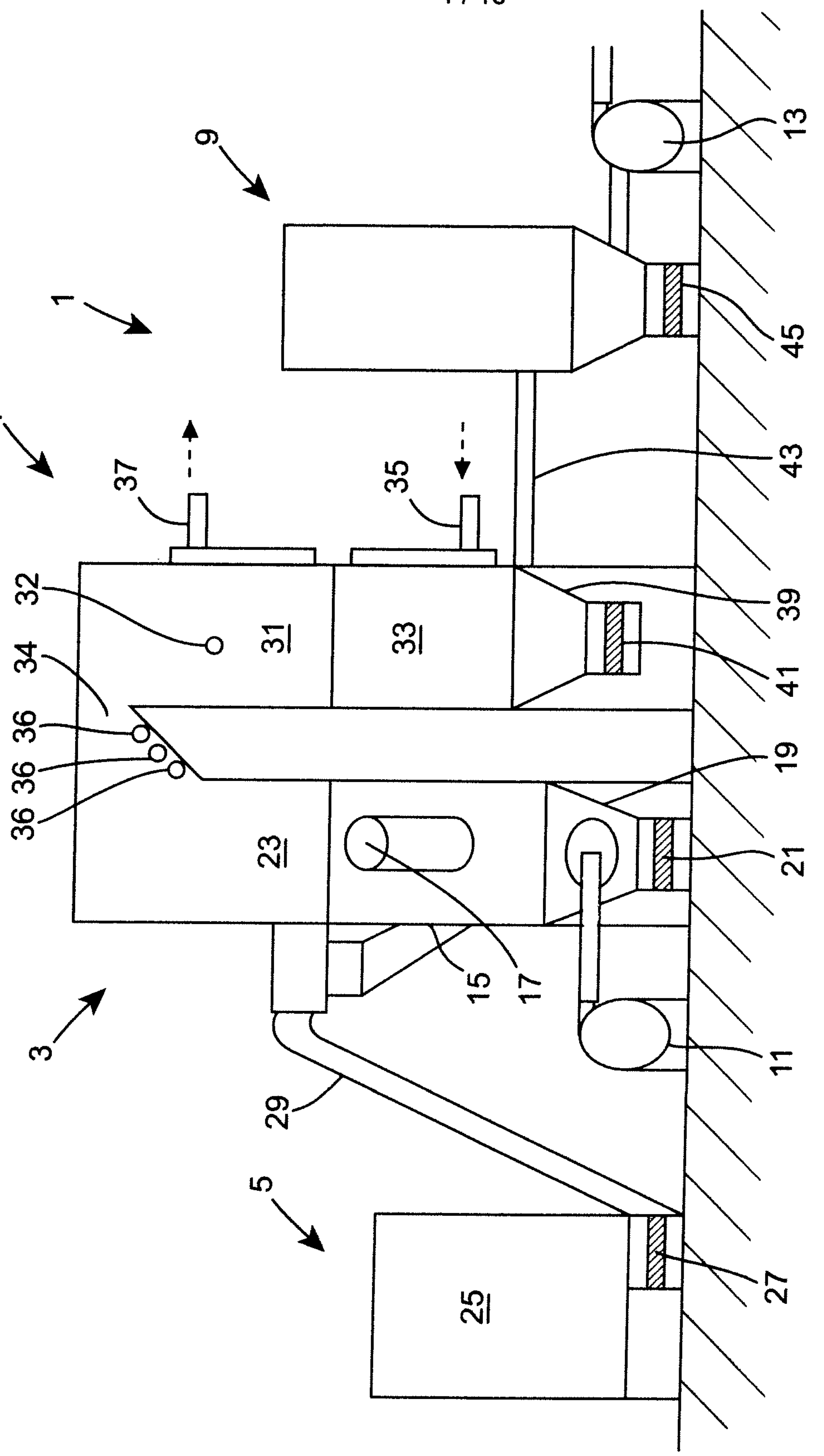

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Fig. 1

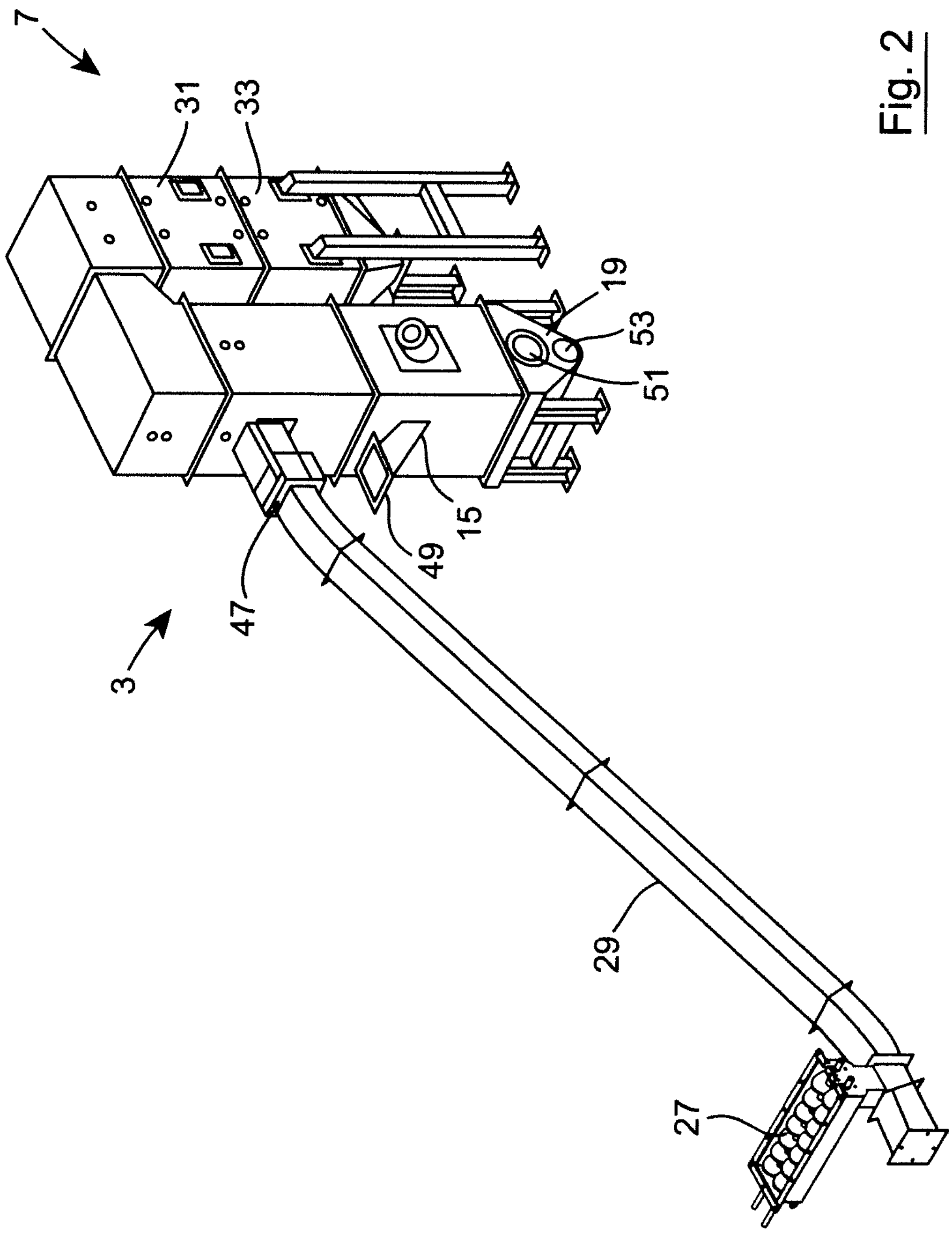

Fig. 2

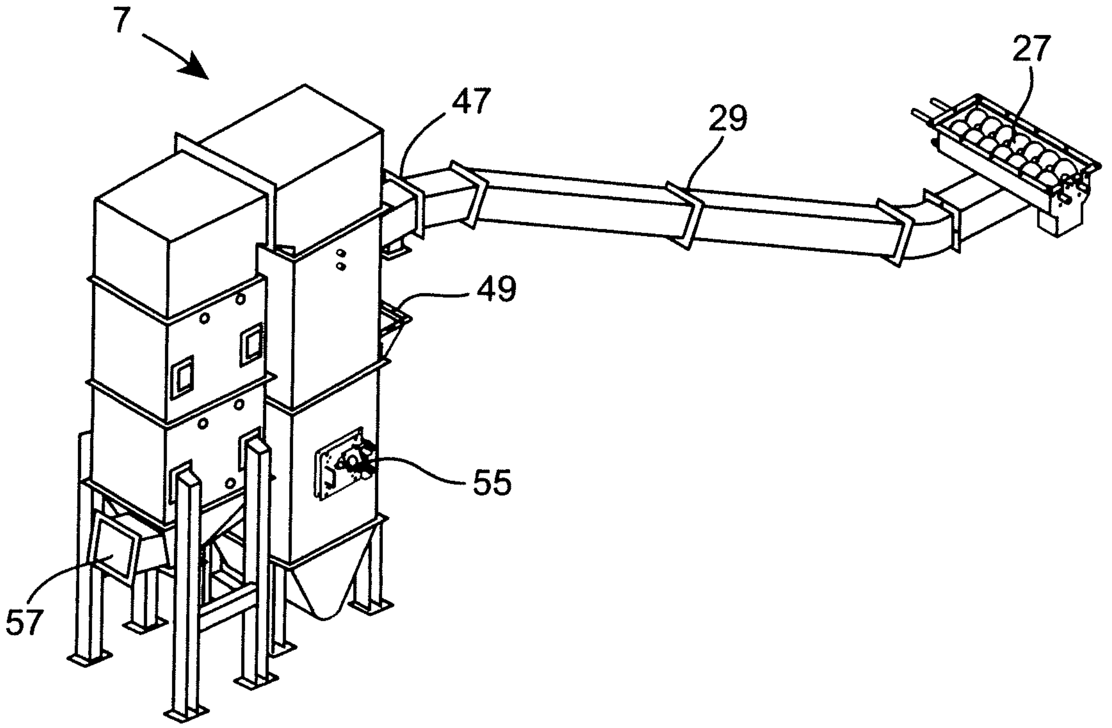

Fig. 3

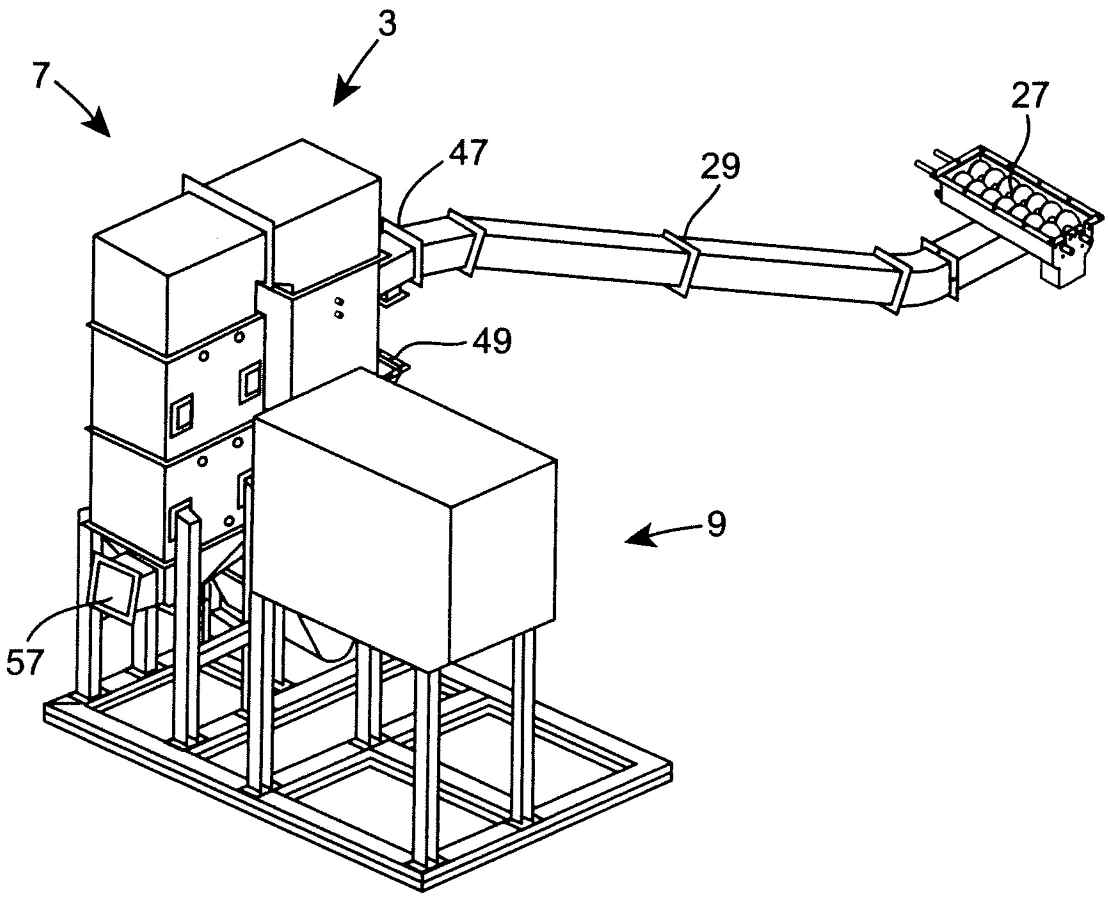

Fig. 4

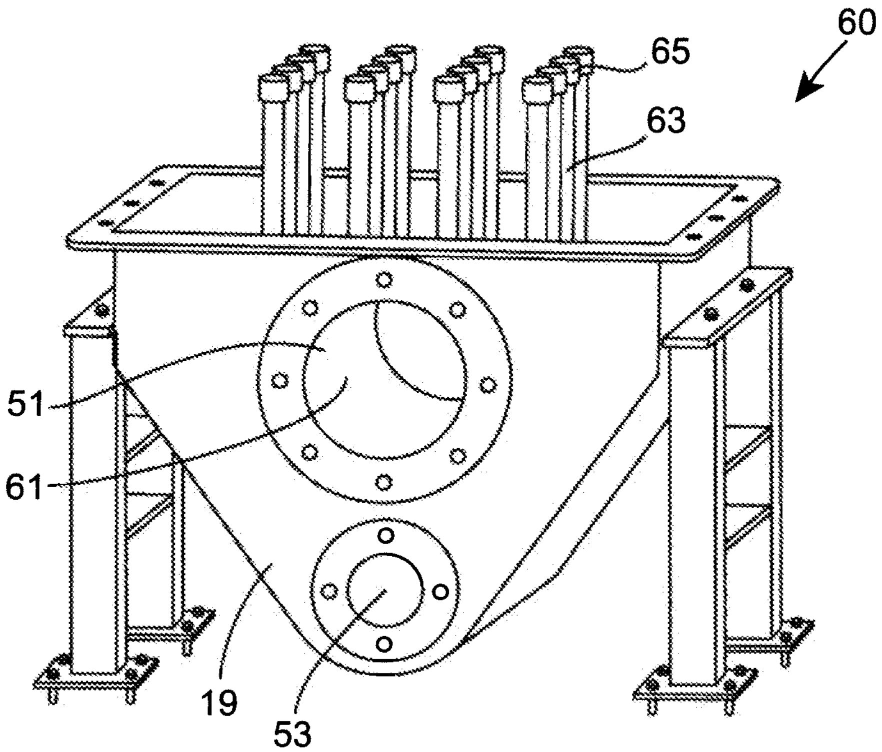

Fig. 5

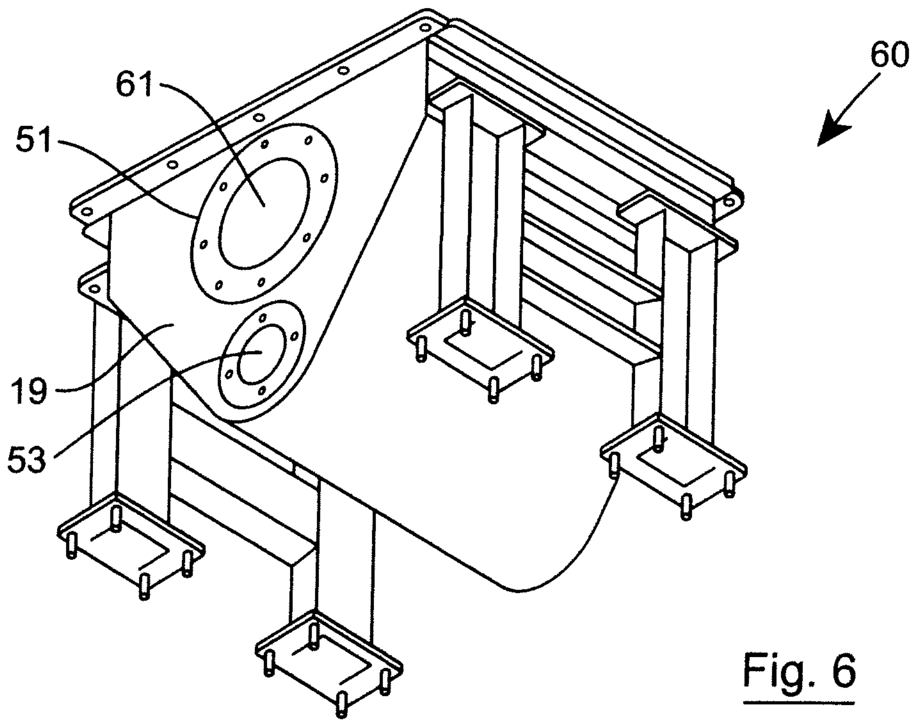

Fig. 6

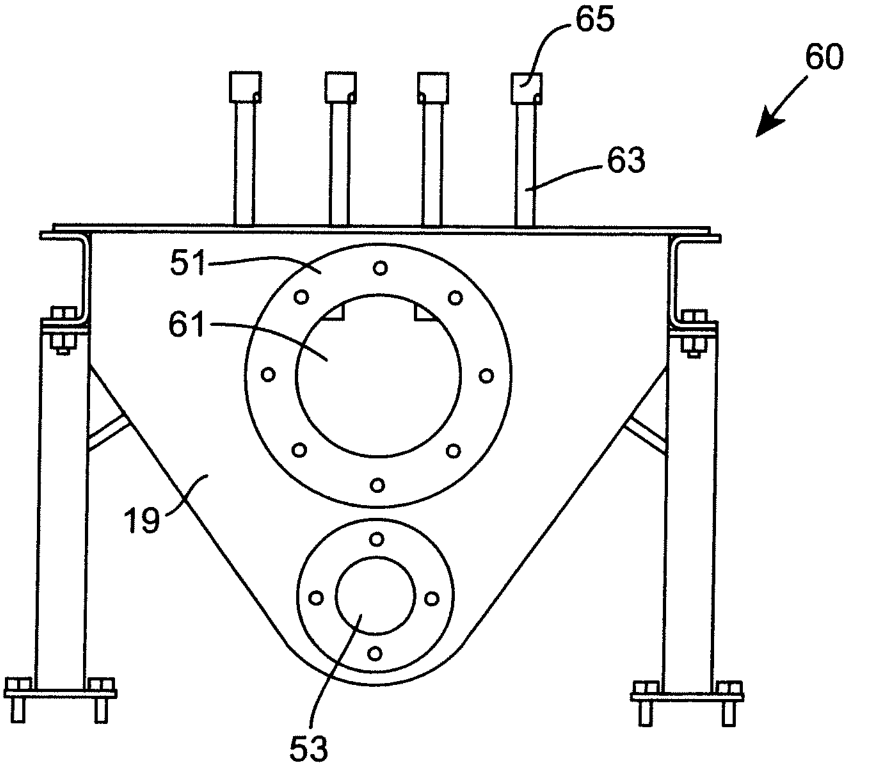

Fig. 7

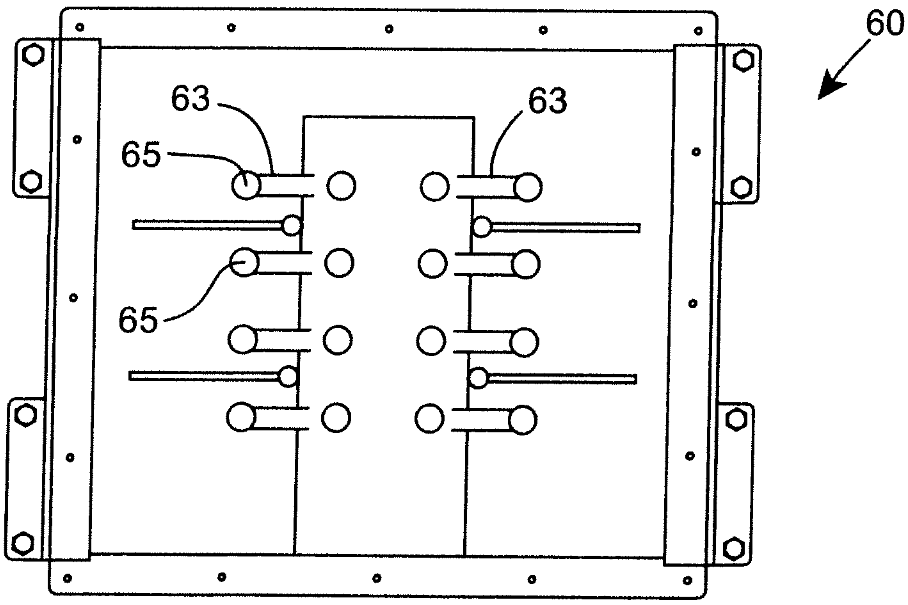

Fig. 8

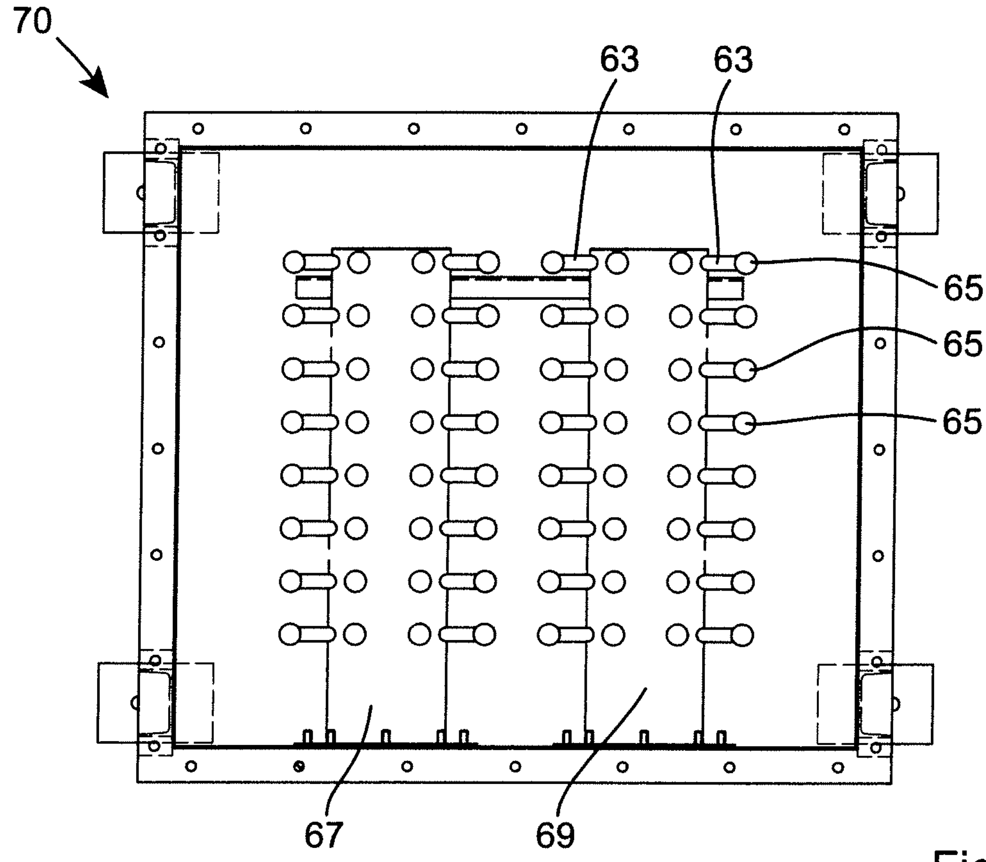

Fig. 9

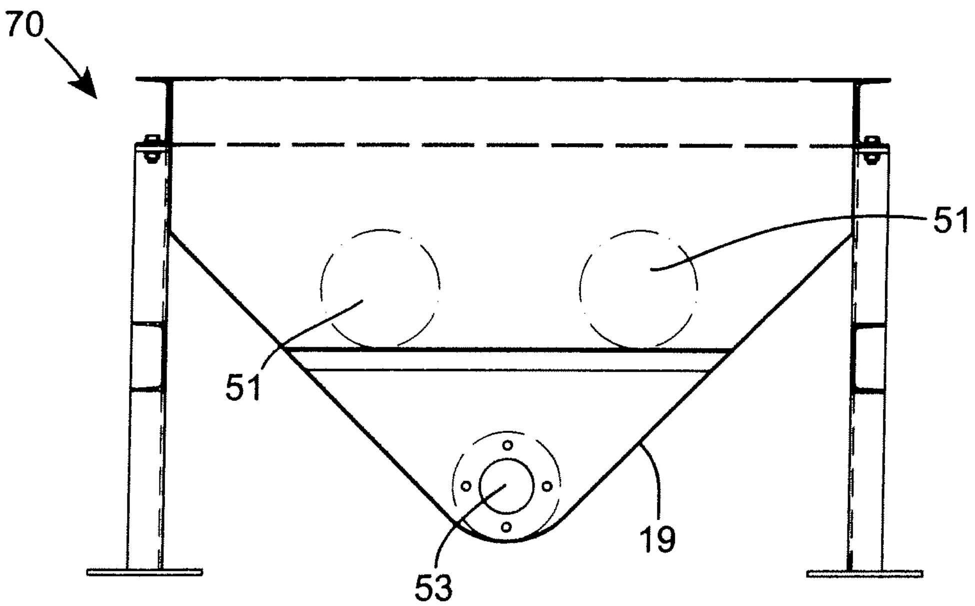

Fig. 10

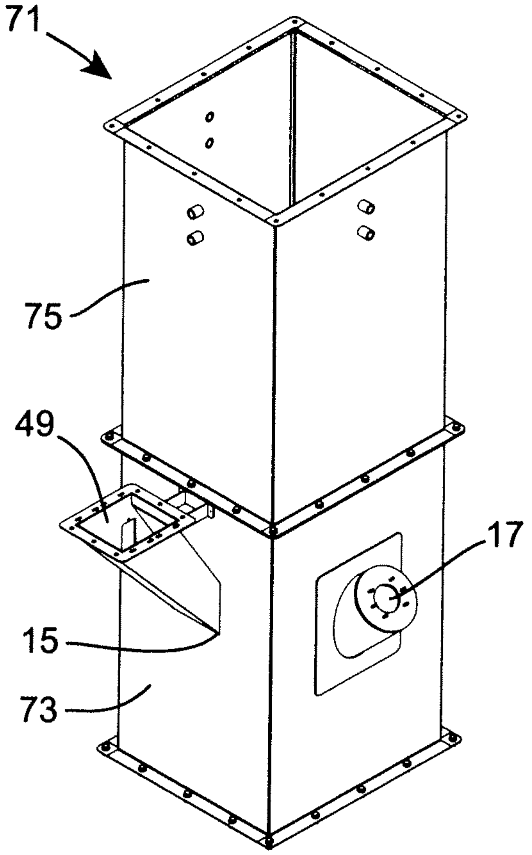

Fig. 11

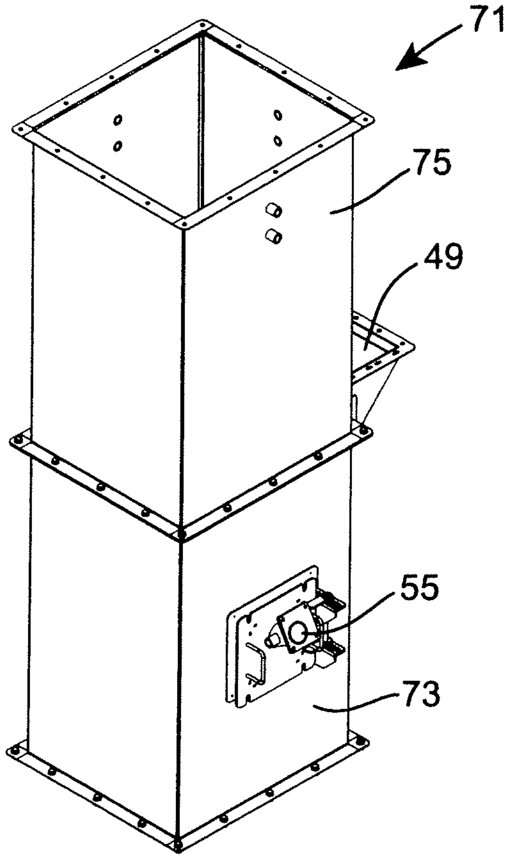

Fig. 12

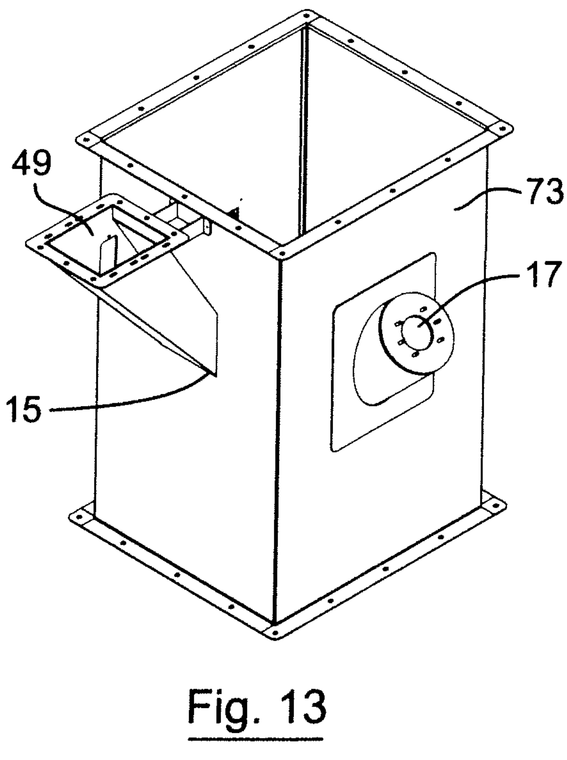

Fig. 13

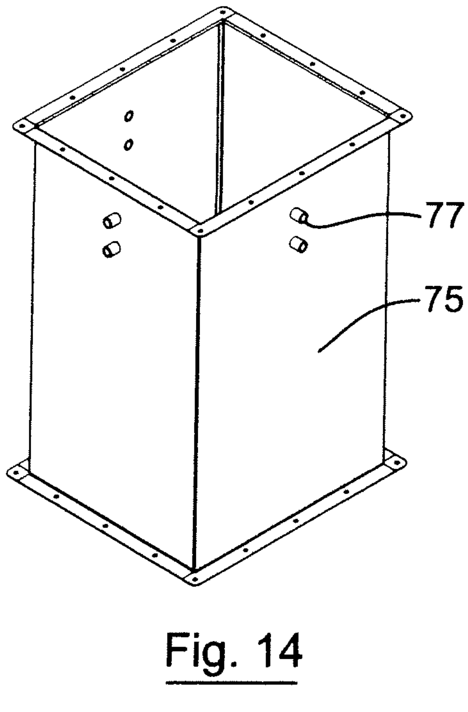

Fig. 14

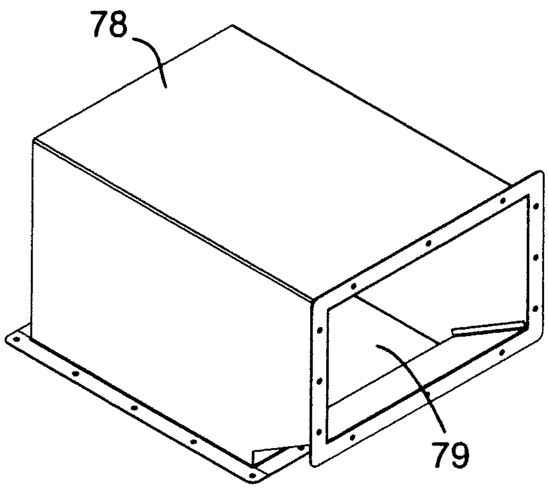

Fig. 15

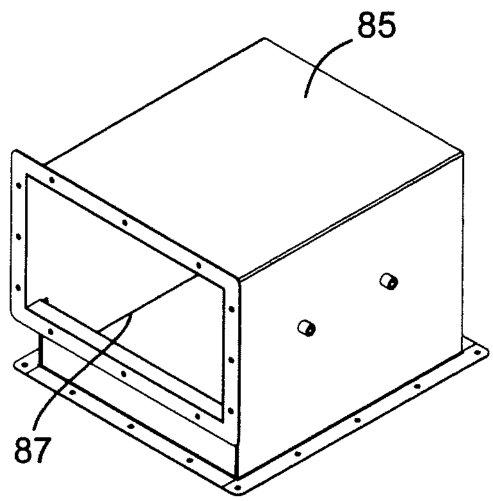

Fig. 18

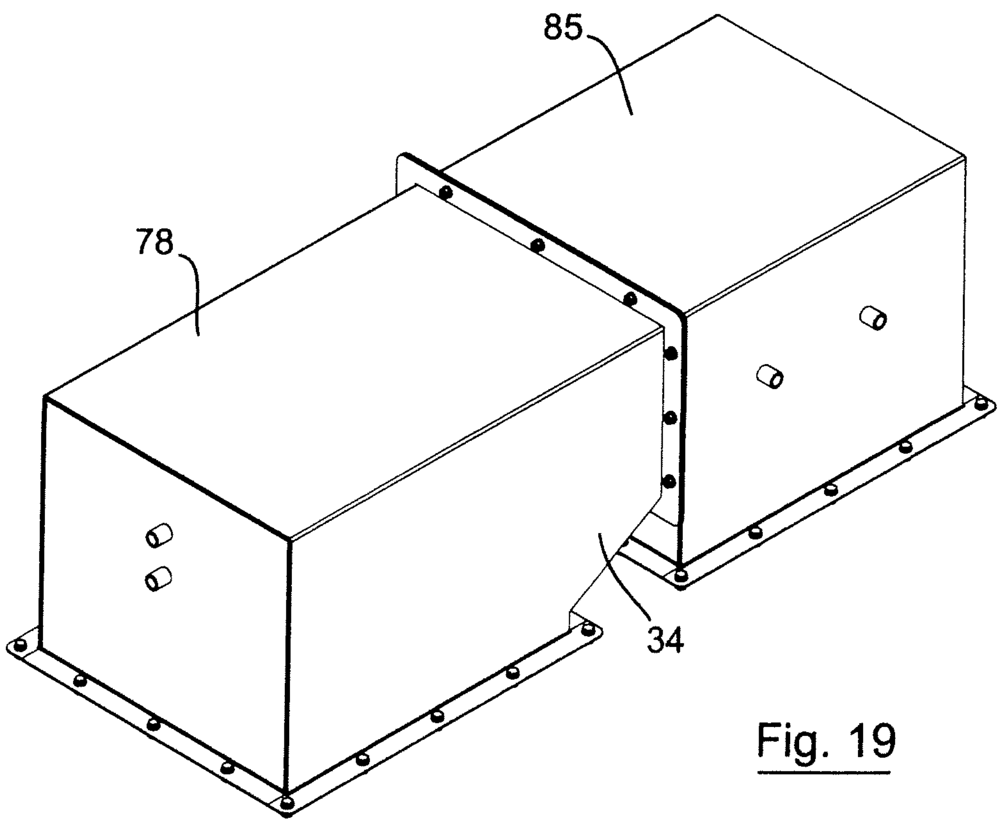

Fig. 19

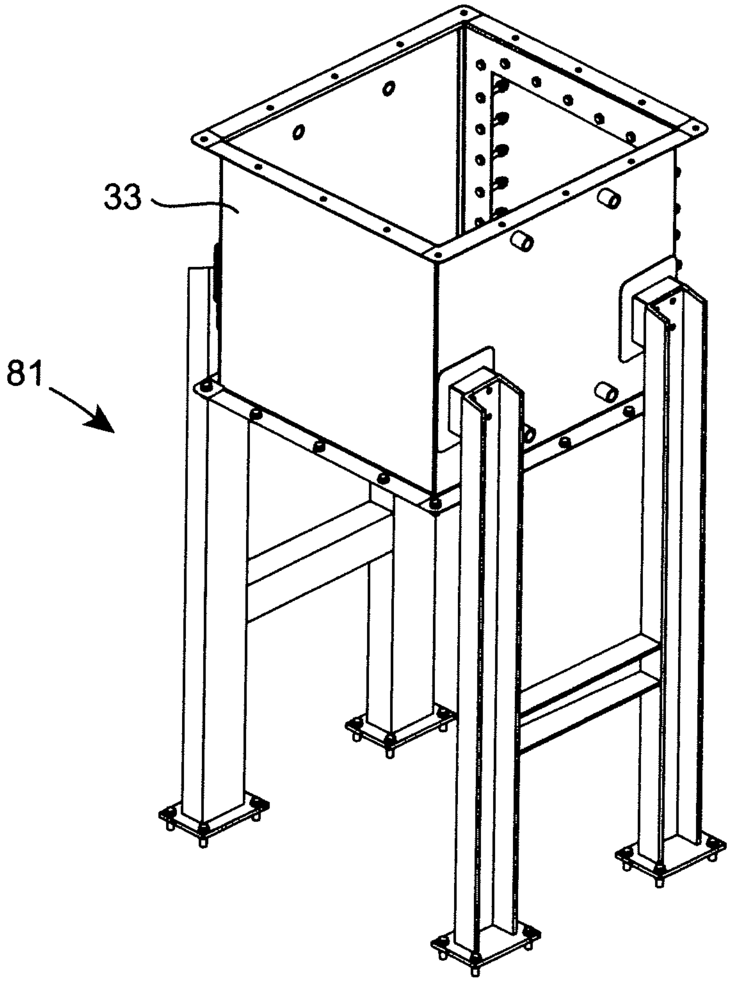

Fig. 16

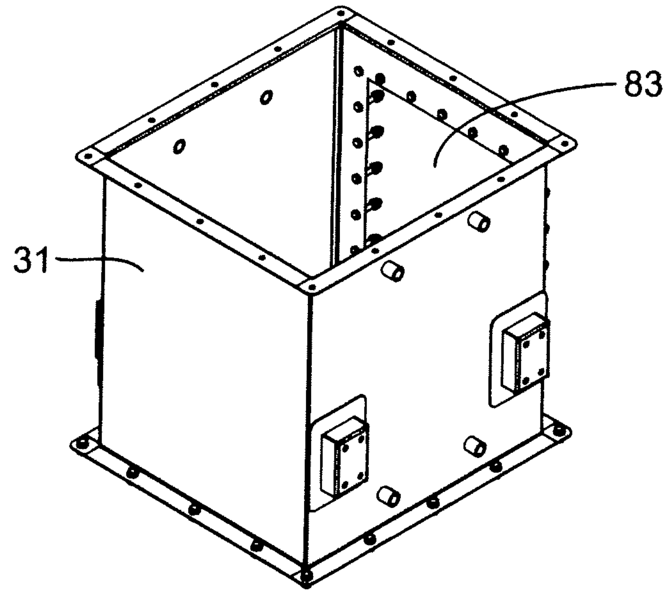

Fig. 17

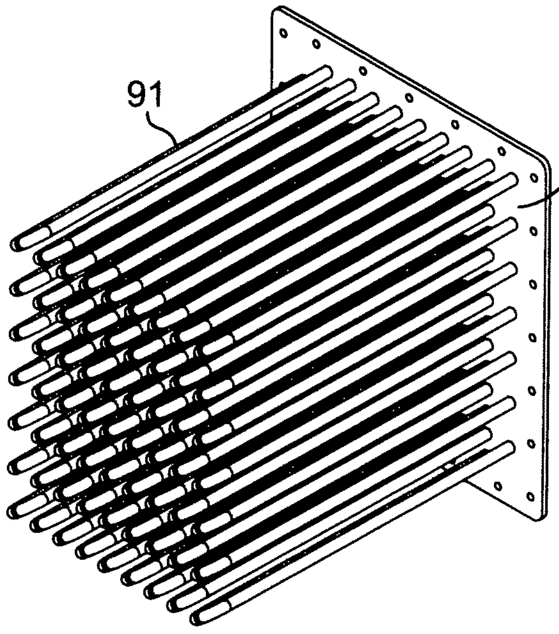

Fig. 20

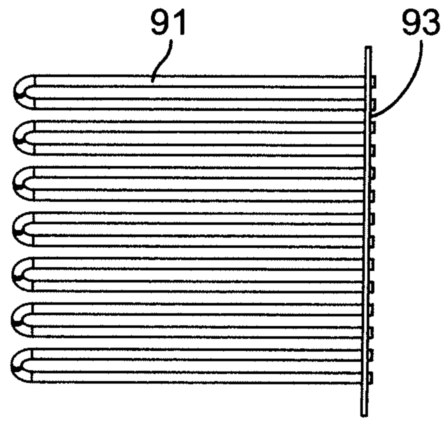

Fig. 21

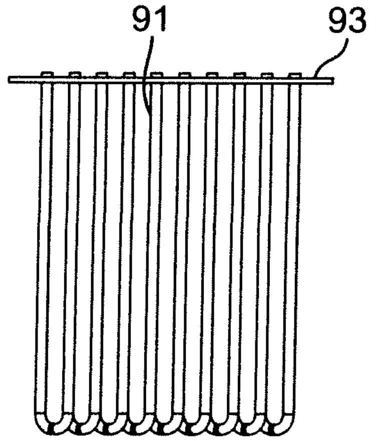

Fig. 22

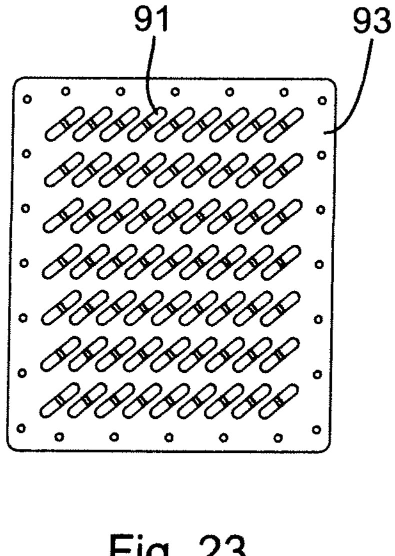

Fig. 23

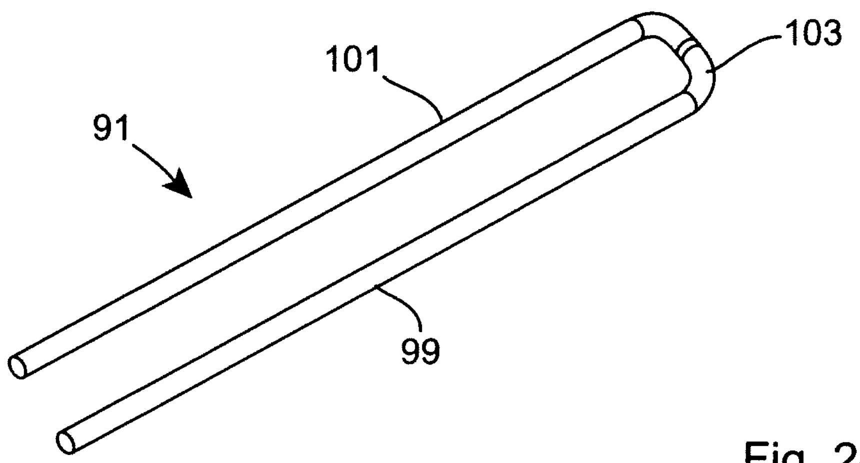

Fig. 24

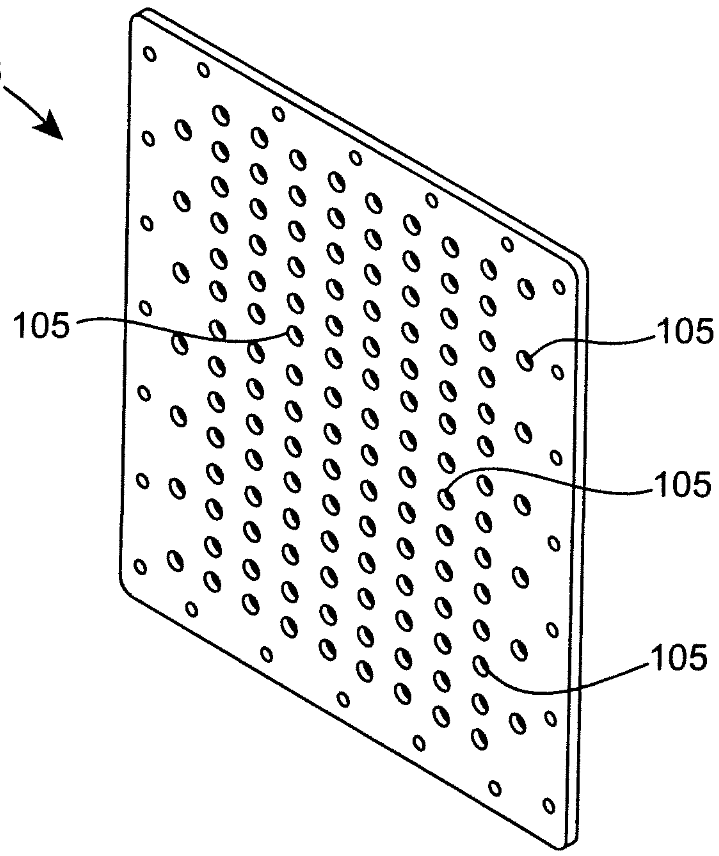

Fig. 25

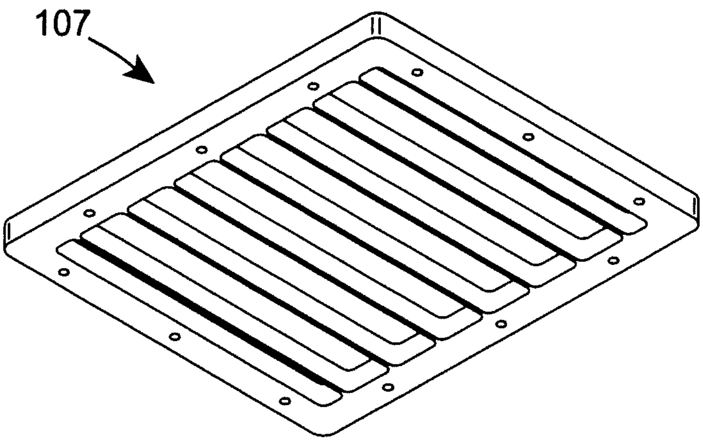

Fig. 26

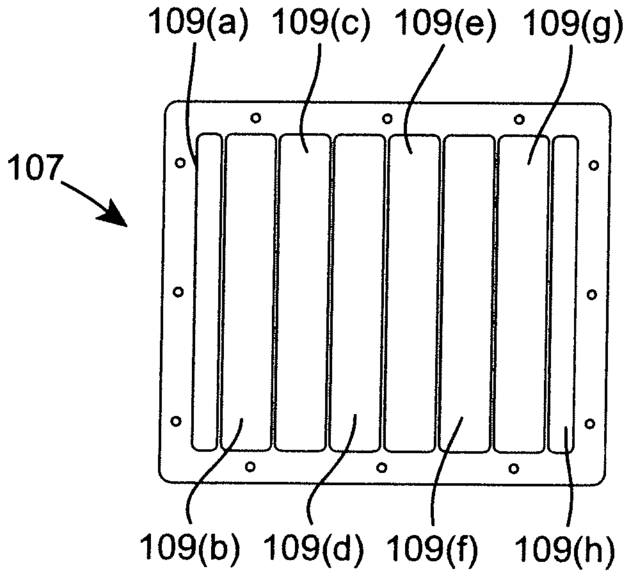

Fig. 27

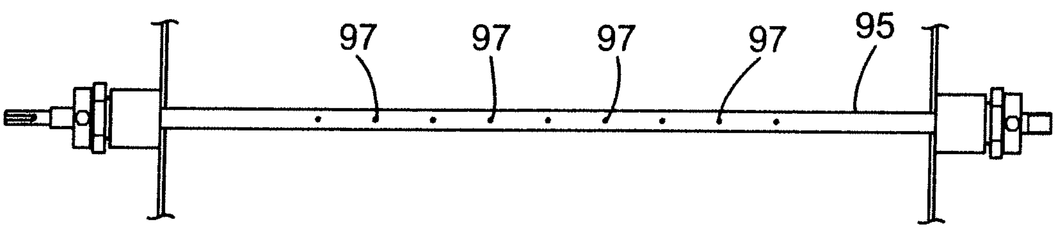

Fig. 28

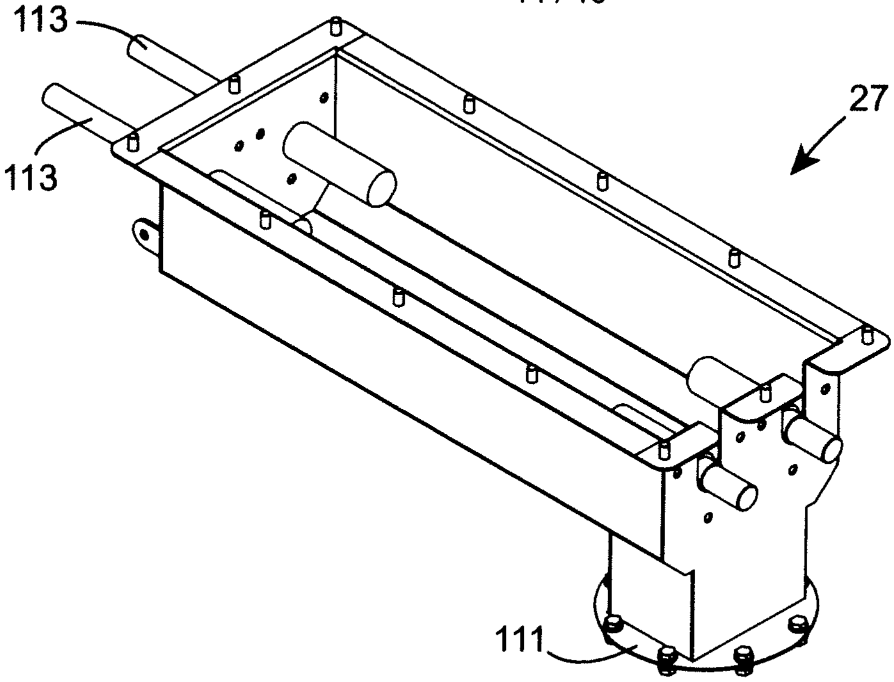

Fig. 29

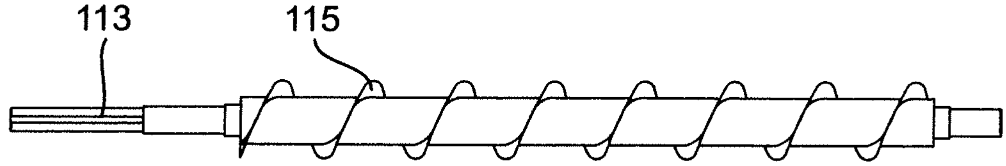

Fig. 30

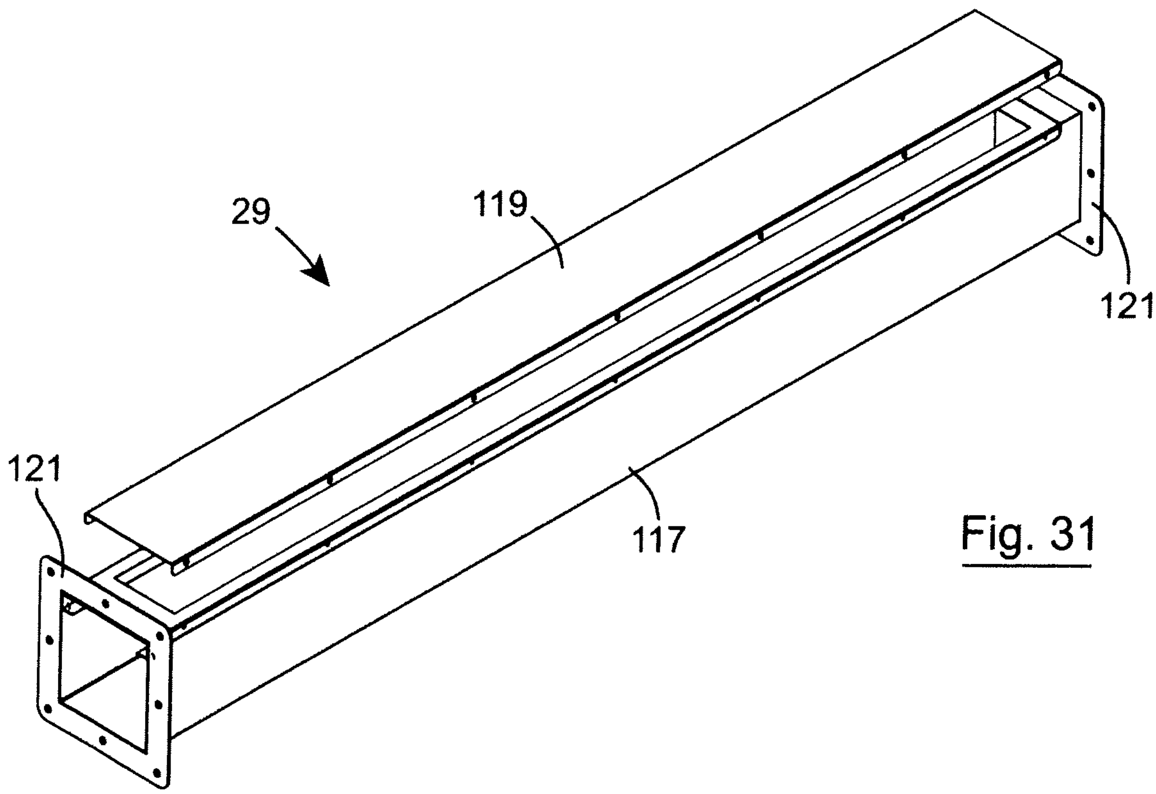

Fig. 31

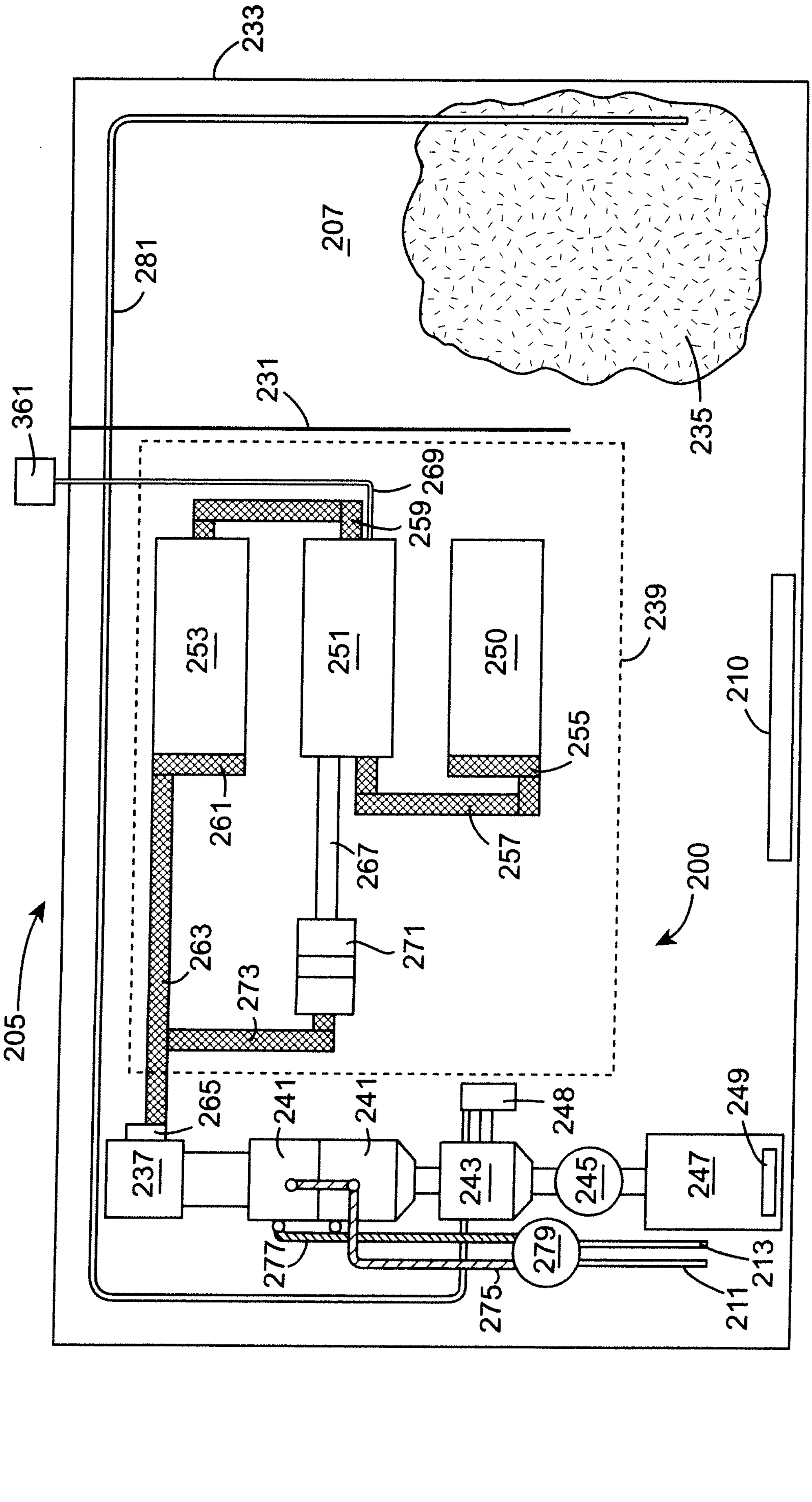
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Fig. 32

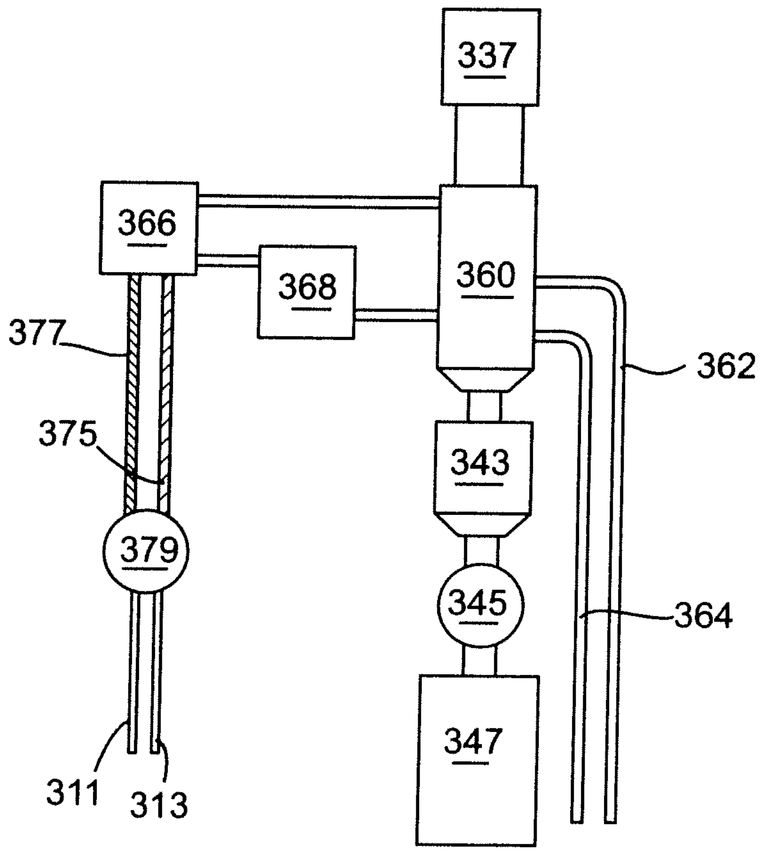

Fig. 33