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(71) Applicants:
- **Hoval Aktiengesellschaft**
  9490 Vaduz (LI)
- **BMA TECH INC.**
  St-Laurent, Quebec H4T 1Y4 (CA)

(72) Inventors:
- **Telian, Markus**
  6912 Hörbranz (AT)
- **Malouin, Louis-Michel**
  St-Laurent,, Québec H4L 5H9 (CA)

(74) Representative: **Zenz**
Patent- und Rechtsanwälte
Rüttenscheider Straße 2
45128 Essen (DE)

(54) Grate and method of burning a granular fuel material

(57) The substantially horizontally-disposed grate is used for burning a granular fuel material, for instance a biomass material, to be fed onto a loading area of the grate while a primary air feed is coming from below the grate. The grate includes a perforated bed floor having a downwardly-sloping upper surface converging towards a discharge opening where char is concentrated as the granular fuel material is burned during operation. The grate also includes an elongated and bottom-perforated char-receiving conduit positioned immediately under the bed floor. The char-receiving conduit has an inlet end positioned under the discharge opening, and an outlet end that is opposite the inlet end. The char-receiving conduit downwardly slopes between the inlet end and the outlet end. A method of burning a granular fuel material is also disclosed. The proposed concept can increase the overall thermal efficiency of a heat generator and reduce gas and particle emissions in the atmosphere.

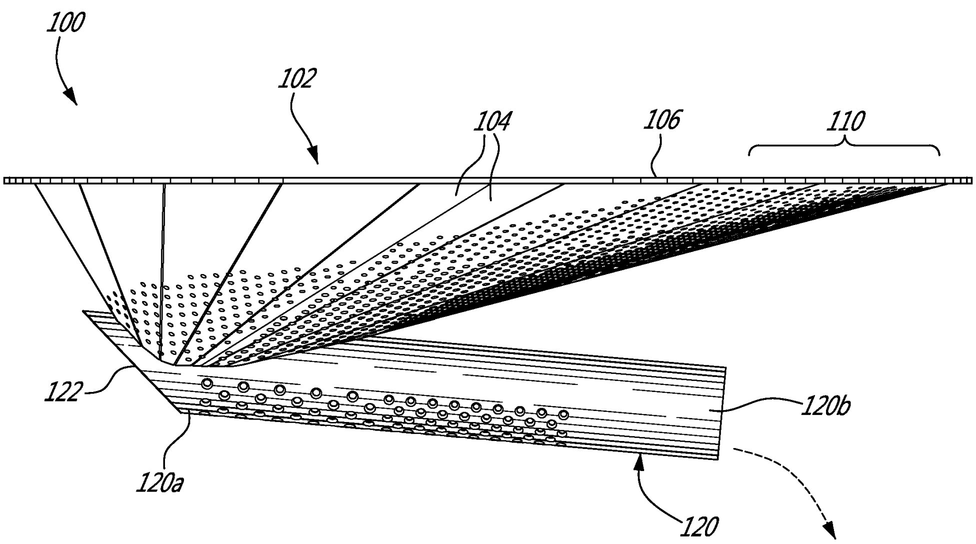

FIG. 2

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Description

TECHNICAL FIELD

[0001] The technical field relates generally to grates and methods of burning granular fuel materials so as to produce heat energy with an increased overall thermal efficiency as well as a reduction of gas and particle emissions in the atmosphere.

BACKGROUND

[0002] Many different models of heat generators have been suggested over the years for burning fuel, thereby producing heat energy for a given purpose. Existing heat generators vary in size, configuration, shape and efficiency, to name just a few of the differences between them. The type of fuel being used to generate the heat and the heat output requirements are two examples of factors that generally have an impact on their design.

[0003] While maximizing thermal efficiency is almost always one of the goals when designing a heat generator, further increasing the thermal efficiency above levels already obtained using existing approaches is a continuous challenge since this has a direct impact on the operational costs. Goals set for reducing gas and particle emissions in the atmosphere also prompts designers to optimize the thermal efficiency, especially in large commercial or industrial installations. One way to express the thermal efficiency of a heat generator is to measure the heat energy output per given quantity of material burned therein.

[0004] Some heat generators are designed for burning one or more granular fuel materials, for instance a biomass material such as corn cobs, sawdust, scrap or loose wood fragments, etc. Many other variants exist. Many such biomass materials are often considered waste by-products and are often simply discarded or not used for generating heat. While most such fuels are not particularly efficient compared to other possible fuels, they have the advantage of being generally economical and widely available in some areas, in particular some rural areas.

[0005] The heat generators designed for burning granular fuel materials often include a grate to support the burning fuel and promote air circulation through it. A grate generally includes perforations and/or spaced-apart bars. Increasing the available air generally increases the combustion efficiency, i.e. the capacity to bum all fuel matter. However, increasing the air feed can also decrease the overall heat transfer efficiency of the heat generator since the temperature of the hot gases from the combustion decreases when the air is in excess. The excess air is also increasing the losses at the chimney by increasing the mass of unused heated air released in the atmosphere. Minimizing the excess air is thus highly desirable for maximizing the thermal efficiency. With a greater thermal efficiency, less fuel is needed and therefore, gas and particle emissions are reduced. A reduction of the excess air can also reduce the amount of particles being carried away out of the chimney.

[0006] While the existing approaches for burning granular fuel materials have been successful in terms of heat production, there is still room for many improvements in this area of technology, particularly for further increasing the overall thermal efficiency.

SUMMARY

[0007] The proposed concept relates to a grate and a method of burning a granular fuel material in which the distribution efficiency of the primary air is controlled using the grate itself. Unlike existing grates, the char that forms near the end of the burning process is concentrated in a conduit located under the perforated bed floor of the grate, where it bums until only ashes are left. This way, the perforated bed floor can always remain covered with granular fuel materials and the primary air is substantially prevented from bypassing the grate through uncovered perforations of the bed floor.

[0008] In one aspect, there is provided a substantially horizontally-disposed grate for burning a granular fuel material to be fed onto a loading area of the grate while an air feed is coming from below the grate, the grate including: a perforated bed floor having a downwardly-sloping upper surface converging towards a discharge opening where char is concentrated as the granular fuel material is burned during operation; and an elongated and bottom-perforated char-receiving conduit positioned immediately under the bed floor, the char-receiving conduit having an inlet end positioned under the discharge opening, and an outlet end that is opposite the inlet end, the char-receiving conduit downwardly sloping between the inlet end and the outlet end.

[0009] In another aspect, there is provided a method of burning a granular fuel material, the method including the concurrent steps of: loading the granular fuel material in a loading area of a substantially horizontally-disposed bed floor; vibrating the bed floor to move the granular fuel material from the loading area towards a discharge opening located away from and vertically below the loading area; feeding primary air across the bed floor, the primary air coming from a bottom side and passing through a multitude of spaced-apart perforations made in the bed floor; drying, mostly by radiation heat, the granular fuel material immediately after the granular fuel material is loaded onto the bed floor; transforming, by pyrolysis, the dried granular fuel material into volatile compounds and char, and generating heat above the bed floor; collecting and concentrating the char passing through the discharge opening into an elongated chamber extending substantially horizontally underneath the bed floor; and generating heat by burning the char inside the chamber as the char is moved from the discharge opening towards an outlet end of the chamber by the vibrations of the bed floor.

[0010] Further details on these aspects as well as other aspects of the proposed concept will be apparent from the following detailed description and the appended figures.

BRIEF DESCRIPTION OF THE FIGURES

[0011]

FIG. 1 is a schematic view illustrating an example of a generic heat generator for burning a granular fuel material;

FIG. 2 is a side view illustrating an example of a grate having a construction based on the proposed concept;

FIG. 3 is a top isometric view of the grate of FIG. 2;

FIG. 4 is a view similar to FIG. 3, taken from another angle;

FIG. 5 is an enlarged top view of the grate of FIG. 2;

FIG. 6 is a side view illustrating another example of a grate having a construction based on the proposed concept;

FIG. 7 is a top isometric view of the grate of FIG. 6; and

FIG. 8 is a bottom isometric view of the grate of FIG. 6.

DETAILED DESCRIPTION

[0012] FIG. 1 is a schematic view illustrating an example of a generic heat generator 10 for burning a granular fuel material. This heat generator 10 can be used, for instance, as a furnace or a boiler. The heat energy can be transferred to a fluid passing through a heat exchanger or be directly used for another purpose, such as to heat a pressure vessel around which the hot flue gases circulate. Other configurations and arrangements are possible as well.

[0013] The heat generator 10 includes a casing 12 inside which a grate 14 is provided. The grate 14 either fills the entire internal width of the casing 12, as schematically shown, or is either mounted on a supporting structure preventing air under the grate 14 from bypassing it around its periphery.

[0014] The grate 14 is designed to hold the granular fuel material while it bums continuously after being loaded thereon and ignited. Ignition is done using one or more of the possible ignition methods, as known to those skilled in the art.

[0015] The grate 14 is disposed substantially horizontally, meaning that the grate 14 is acting as a receptacle over which the granular fuel material is supported by gravity. An example of granular fuel material is a biomass material, such as corn cobs, sawdust, scrap or loose wood fragments, etc. Coal is another example of a granular fuel material. Many other variants exist. The granular fuel material can be a homogenous material or a mix of two or more materials, regardless whether the expression refers to "material" or "materials". Also, the term "granular" as used in the present context means a particle or a small piece, such as for example but not limited to, having a size ranging from about a fragment of a few millimeters in length to about a coarse granule of a few centimeters in length, as generally understood by those skilled in the art. When used with "fuel material" or "fuel materials", the term "granular" refers to a burnable substance that can be handled in bulk and that is not a gas or a liquid, as generally understood by those skilled in the art.

[0016] For the sake of simplicity, the granular fuel material will simply be referred to as "fuel" from this point onwards.

[0017] As schematically shown in FIG. 1, the fuel is fed to the grate 14 from a fuel source 16. The grate 14 is configured and shaped to hold a given quantity of fuel and fuel will cover almost the entire bed floor when the heat generator 10 is in operation. The fuel is loaded onto the grate 14 at a loading area located on the upper surface of a perforated bed floor of the grate 14. The fuel falls by gravity onto the bed floor, for instance coming from an endless screw conveyor. Variants are possible as well.

[0018] Air coming from a primary air source 18 is supplied under the grate 14 when the fuel is burning. The primary air source 18 is for instance a blower or any other suitable device. The primary air source 18 generates a primary air feed 20. The primary air feed 20 reaches the bottom of the grate 14 and then passes through perforations provided across the thickness of the perforated bed floor because of a pressure differential between both sides thereof. The exact size, shape and spacing of the perforations depend on various factors. The size of the perforations will depend, among other things, on the size of the fuel pieces. It is of course desirable to prevent fuel pieces from falling by gravity through the perforations. Still, the perforations are not necessarily made or all made with a circular cross section. For instance, the perforations can be oblong or can even have any other shapes, such as rectangular, octagonal, etc. They can also have an irregular shape or even be tapered. Other variants are possible.

[0019] The burning process occurring at the grate 14 generates heat (radiant and convective) as well as gases, among other things. These gases rising from the grate 14 still contain inflammable gases in form of volatile compounds, especially when the primary air feed 20 does not supply enough oxygen for a complete combustion. An example of volatile compound is carbon monoxide (CO). The combustion is completed in a zone 22 located above the grate 14. This zone 22 receives additional air from a secondary air source 24. The secondary air source

24 generates a secondary air feed 26. The secondary air source 24 is for instance a blower or any other suitable device. Typically, the primary air feed 20 is about 35% of the total supplied air and the secondary air feed 26 is thus about 65% of the total supplied air. The relative proportions of the primary and the secondary air feed can be controlled manually and/or using an automated control system. The control system can also modulate the air flow in function of the amount of fuel being supplied. Other configurations, arrangements and proportions are also possible.

[0020] In the illustrated example, the hot gases coming from the zone 22 pass through a heat exchanger 28 where convective heat energy is collected. The heat exchanger 28 also receives radiant heat from the burning fuel. This heat exchanger 28 has an internal fluid circuit connected to an incoming conduit 30 and an outgoing conduit 32. The outgoing conduit 32 sends a heated fluid where or closer to where the heat energy is needed. The incoming conduit 30 and the outgoing conduit 32 can form a closed-loop circuit and/or an opened-loop circuit, depending on the needs. Variants are also possible.

[0021] In some implementations, one or more additional heat exchangers (not shown) can be provided to recover more heat energy from the gases downstream the heat exchanger 28. The gases eventually exit the casing 12 as flue gases 34. The flue gases 34 can be discarded through a chimney and/or used in another process. It should be noted that the flue gases 34 often contain small particles in suspension. Nevertheless, they will still be referred to as "gases" for the sake of simplicity.

[0022] The illustrated heat generator 10 is designed to be operated in a continuous manner, meaning that the fuel bums continuously for as long as fuel is supplied or unless the combustion is abruptly stopped for some reason. Accordingly, fuel is loaded continuously or at given intervals (regular or not) while the burning process is ongoing. A portion of the fuel that was put on the perforated bed floor will transform into granular char and a portion will transform into the volatile compounds to be burned as well in the zone 22. Typically, about 80% of the carbon from the fuel will be transformed in volatile compounds and about 20% will become char. The combustion of the volatile compounds forms the visible flames in a fire while the char is seen as glowing red coals or embers which often bum without the presence of flames. On average, the volatile compounds will require about two times more oxygen than char to burn.

[0023] The char will eventually form ashes and other solid debris that need be removed from the grate 14. Debris can be, for instance, fragments or pieces (such small rocks, sand, metal fragments, etc.) that cannot bum at the temperatures involved. Other kinds of debris are also possible. For the sake of simplicity, the terms "ash" and "ashes" are meant to include debris present therein, if any. In FIG. 1, the ashes are removed from the bottom of the grate 14 and out of the casing 12 using an ash removal system, which system is schematically depicted in FIG. 1 at 36. The ash removal system 36 can include, for instance, an endless screw carrying the ashes outside for disposal. Other kinds of systems are also possible.

[0024] In use, the grate 14 is vibrated to progressively move the fuel over the perforated bed floor of the grate 14. The vibrations can be generated using a vibrations generator that is connected to or mounted on the grate 14. The vibrations generator is schematically depicted in FIG. 1 at 40. The vibration generator 40 of the illustrated example is located outside the casing 12 and is mechanically connected to the grate 14 using a link that is schematically depicted in FIG. 1 at 42. This vibration generator 40 could also be located inside the casing 12 in some implementations. Other configurations and arrangements are also possible. The grate 14 is supported at its periphery by a suitable supporting arrangement which, however, is not part of the proposed concept and does not need to be described furthermore. The vibrations can be continuous or intermittent, depending on the implementations.

[0025] The grate 14 can be made of a material such as a metal or a coated metal capable of withstanding the temperatures involved over long time periods while the fuel is burning. These temperatures can be up to about 800°C, sometimes even more.

[0026] If desired, the grate 14 can include an internal cooling circuit, for instance an internal cooling circuit having a network of conduits designed to keep some of the parts of the grate 14 below a given temperature. The internal cooling circuit and the associated cooling system located outside the casing 10 are schematically depicted in FIG. 1 at 50.

[0027] The grate 14 can be constructed like the one of the example illustrated in FIG. 2. In FIG. 2, this grate is referred to as the grate 100. The grate 100 has a perforated bed floor 102 that is generally conical in shape. Its periphery is also generally circular in shape, as best shown in FIGS. 3 and 4.

[0028] FIGS. 3 and 4 are both top isometric views of the grate 100. FIG. 5 is an enlarged top view of the grate 100.

[0029] The perforated bed floor 102 of the illustrated grate 100 is made of a plurality of juxtaposed flat panels 104, for example panels welded together along their edges so as to form a downwardly-sloping upper surface. The average inclination of the bed floor 102 can be generally between 5 and 25° with reference to the horizontal, although other values are possible as well. The panels 104 form a funnel-like structure that will hold the fuel when the grate 100 is disposed substantially horizontally. The illustrated grate 100 also includes a circular rim 106 located around the periphery of the bed floor 102. The rim 106 has a plurality of axisymmetric holes 108 for connecting the grate 100 to a supporting arrangement or the like.

[0030] It should be noted that the bed floor 102 can be constructed differently. For instance, one can use a single panel and shape it as desired in a large press or the like. Other constructions and ways of mounting the grate 100 inside the casing 10 are also possible.

[0031] The grate 100 has a loading area 110. The upper surface of the bed floor 102 converges towards a discharge opening 112 that is somewhat located away from the loading area 110. Also, the discharge opening 112 of the illustrated grate 100 is offset with reference to a geometric center of the upper surface of the bed floor 102. This was made to maximize the length of the path of the fuel over the grate 100. Nevertheless, using another configuration is also possible.

[0032] The discharge opening 112 of the illustrated grate 100 is located within the periphery of the upper surface of the bed floor 102, thus inside the rim 106. Variants are possible as well. For instance, one can design a grate with a discharge opening 112 that is located at the edge of the periphery of the bed floor 102.

[0033] In use, the various steps of the burning process occur concurrently since the fuel bums continuously, unlike for instance a heat generator using a liquid fuel or gas fuel for which interrupting the burning process is much easier. Once on the bed floor 102, the fuel is vibrated and will progressively move from the loading area 110 towards the discharge opening 112. The discharge opening 112 is located away from and vertically below the loading area 110. Thus, using the vibrations, the fuel will progressively move towards that location as it bums.

[0034] As best shown in FIG. 2, the grate 100 includes an elongated and bottom-perforated char-receiving conduit 120 positioned immediately under the bed floor 102. The illustrated char-receiving conduit 120 has an inlet end 120a which includes an upper opening positioned directly under the discharge opening 112, and an open-ended outlet end 120b that is opposite the inlet end 120a. The char-receiving conduit 120 downwardly slopes between the inlet end 120a and the outlet end 120b. The average inclination can be generally between 5 and 20° with referenced to the horizontal, although other values are also possible as well.

[0035] The char-receiving conduit 120 is entirely supported by the bed floor 102. For instance, the char-receiving conduit 120 of the grate 100 can be welded or otherwise attached underneath the bed floor 102 around the periphery of the discharge opening 112. One can also use brackets or the like, if desired. The bed floor 102, the rim 106 and the char-receiving conduit 120 form a compact monolithic unit. Variants are possible as well.

[0036] In the illustrated example, the char-receiving conduit 120 is substantially tubular in shape. Nevertheless, other shapes and configurations are possible as well. For instance, the char-receiving conduit 120 could have a rectangular cross section or any other shape (oval, triangular, etc.) The size and shape of the char-receiving conduit 120 can also vary along its length. The inlet end 120a of the char-receiving conduit 120 includes an inclined end wall panel 122 so that the char received from the discharge opening 112 can only go towards the outlet end 120b. The outlet end 120b, however, is open ended. Alternatively, one can provide a char-receiving conduit 120 with an end wall panel (not shown) at the end 120b and use a large bottom opening adjacent to the end 120b as the ash outlet/air intake.

[0037] The cross-sectional area of the char-receiving conduit 120 can be generally about 2 to 4% of the area of the upper surface of the bed floor 102. These values should provide very good results in most implementations. Nevertheless, other values are possible as well.

[0038] The illustrated grate 100 has a vertical plane of symmetry depicted by line 130 in FIG. 5. The char-receiving conduit 120 of the grate 100 has a longitudinal axis that extends substantially parallel to the plane of symmetry 130. This way, the heat generated inside the char-receiving conduit 120 will spread evenly on both sides of the bed floor 102. Nevertheless, one can construct a grate that is not symmetrical or not entirely symmetrical.

[0039] One of the goals of the grate 100 is to maximize the thermal efficiency of the heat generator by optimizing the use of the amount of the primary air from the primary air feed coming from below the grate 100. The approach involves using different amounts of air for the different stages of the burning process occurring on the grate 100. It also involves the fact that the perforations on the bed floor 102 are always covered with a layer of fuel by way of the concentration of the fuel matter along the end of the grate 100 and that the concentrated char will bum under the bed floor 102 in a specially and specifically designed component of the grate 100.

[0040] The stages of the burning process can be roughly segmented, for instance, as a drying stage, a pyrolysis stage, a fuel combustion stage and a char combustion stage. While the boundaries between the various stages are not necessarily clearly visible in practice within the fuel mass, it is possible to predict by mathematical models based on the physic of combustion of fuel where each stage will approximately happen for a given type of fuel. The present concept uses this predictability to better control the amount of the primary air to be supplied to the fuel and optimizing the solution through the design of the grate 100 itself. This is done by selecting one or more perforation patterns of the grate 100 instead of using a segmented primary air feed, for example. A segmented primary air feed generally involves using a plurality of compartments directing different streams of the primary air to specific locations on the underside of a grate. While this approach may perhaps still be useful in some implementations, it is more desirable to use only a single primary air feed to lower both costs and complexity.

[0041] The first stage is the drying stage. Not all fuels necessitate a drying stage but most biomass fuel materials will require one since they often have relatively high moisture contents. In the drying stage, the fuel mostly uses the intense radiant heat coming from the combustion in the subsequent stages to evaporate this moisture. Convective heat may also contribute to drying the fuel but at a lesser extent. The primary air requirement is the lowest at the drying stage since there is essentially no combustion. The drying stage occurs at and around the loading area 110, generally at a temperature of about 100°C.

[0042] The next stage is the pyrolysis stage. Pyrolysis can be broadly defined as a thermochemical decomposition of organic material at elevated temperatures. Using the oxygen contained in the primary air, the carbon material then transforms itself into char (fixed carbon) and volatile compounds (volatile carbon). The volatile compounds will generally start forming at about 250°C. The rate of pyrolysis will increase as the temperature increases in the combustion chamber. The temperature in the combustion chamber can even reach as high as 1200°C depending on the type of fuel used.

[0043] The combustion stage occurs after the pyrolysis stage. In the fuel combustion stage, more air (thus more oxygen) is generally needed compared to the preceding stages. Generally, the primary air feed is calculated so that the entire oxygen content of the primary air will be used at the grate 100. The combustion of the volatile compounds will thus be incomplete. The combustion will be completed above the grate 100 using the secondary air provided downstream. It should be noted that the production of volatile compounds also continues during the combustion stage. It will continue until only char is left. The main differences between the pyrolysis stage and the combustion stage include the amount of oxygen available and the amount of heat being generated.

[0044] The grate 100 is designed so that most of the fuel becomes char when it reaches the discharge opening 112. The char then slowly sink into the char-receiving conduit 120, where it is further concentrated and where it bums right underneath the bed floor 102. The char-combustion stage is the last stage of the burning process.

[0045] Ashes are formed as a result of the combustion of the char and, as aforesaid, exit through the open-ended outlet end 120b. Ashes generally represent from 1 to 4% of the total mass of fuel provided over the grate 100, depending on the fuel grade.

[0046] It should be noted that while char is also some fuel by definition, the skilled reader will understand that the distinction between "fuel" and "char" is only made in the context of the transformation of the fuel during the combustion process.

[0047] As shown in FIG. 5, the bed floor 102 of the illustrated grate 100 has five different sets of perforation to control the amount of the primary air passing there through. The perforations of the perforation patterns vary in size, shape, density and/or diversity. Each perforation pattern on the bed floor 102 forms what is referred to hereafter as a region. The density refers to the relative spacing between the perforations while the diversity refers to the possible combination of two or more different kinds of perforations. Still, one can use identical perforations in some or even all of the regions. One can also design a grate with fewer regions of distinct perforation patterns. Using a single region is even possible is some very simple designs.

[0048] During operation of the heat generator, fuel is loaded on the perforated bed floor 102 of the grate 100 up to a given level. Because of the vibrations to which the grate 100 is subjected, the fuel will be scattered over the entire bed floor 102 and the fuel level will tend to be leveled on the top thereof. The perforations of the bed floor 102 are constantly covered by some fuel and the thickness of the fuel mass is thus another factor to consider. Constantly covering the perforations will create an air restriction, especially if the fuel pieces are relatively small as they will be more densely packed than larger ones, thereby preventing the primary air from by-passing the grate 100 to create excess air diluting the hot gases above the grate 100. This approach will greatly improve the overall thermal efficiency.

[0049] In the illustrated grate 100, the first region is adjacent to the periphery of the upper surface of the bed floor 102 and includes the loading area 110. This first region corresponds approximately to the drying stage for the fuel pieces that are near the upper surface of the bed floor 102.

[0050] It should be noted that during operation, fuel is loaded, as aforesaid, up to a given level on the perforated bed floor 102. Therefore, fresh fuel arriving at the loading area 110 over the fuel mass already present will not necessarily follow a straight line from the loading area 110 to the discharge opening 112. For instance, some fuel pieces will rather follow an arcuate path near the top of the fuel mass. The flow of fuel on the bed floor 102 is tridimensional in nature when considering the fuel mass. The design of the grate 100 takes into account the time taken by all fuel pieces to travel from the loading area 110 down to the discharge opening 112. This is the reason why the first region (which is two-dimensional in nature) relates to the corresponding perforation pattern and is only indicative of where the drying stage approximately occurs for the fuel pieces that are near the upper surface of the bed floor 102.

[0051] The second region of the illustrated grate 100 is located closer to the discharge opening 112 and surrounds the periphery of the first region. It corresponds approximately to the pyrolysis stage for the fuel pieces that are near the upper surface of the bed floor 102.

[0052] As can be seen in FIG. 5, the first region and the second region are wider along the plane of symmetry 130 than on their sides. This takes into account the fact that fuel pieces will tend to travel more quickly when they are near the upper surface of the bed floor 102 compared to fuel pieces at the top of the fuel mass. Another factor that can be taken into account is the heat. Fuel pieces receiving more heat than others will dry faster and complete the pyrolysis stage faster, for instance.

[0053] The third region of the illustrated grate 100 is located between the periphery of the second region and the periphery of the discharge opening 112. This third region corresponds approximately to a portion of the fuel combustion stage for the fuel that is near the upper surface. The fourth and fifth regions are located further away from the loading area 110. They correspond approximately to other portions of the combustion stage for the fuel pieces that are near the upper surface of the bed floor 102.

[0054] As aforesaid, the transformation of the fuel into the volatile compounds and the char is completed about the time the fuel (now in the form of char) reaches the discharge opening 112. Char pieces will then fill the entire width of the discharge opening 112 and will slowly progress into the char-receiving conduit 120.

[0055] The char-receiving conduit 120 has bottom perforations to receive primary air. These perforations can include one or more different patterns. For instance, the perforations near the outlet end 120b can be smaller to prevent the progressively smaller char pieces and the ashes from falling through. Air can also enter the char-receiving conduit 120 through the outlet end 120b. Thus, as a skilled reader will understand in the context, the outlet end 120b of the char-receiving conduit 120 is also a primary air inlet and the discharge opening 112 is also a primary air and combustion gases outlet.

[0056] In use, the char will progress along the char-receiving conduit 120 because of the vibrations to which the grate 100 is subjected. The gases resulting from the combustion of the char will escape through the discharge opening 112. The thickness of the char layer inside the conduit 120 will diminish progressively from the inlet end 120a to the outlet end 120b. The perforations of the char-receiving conduit 120 near the outlet end 120b will only be covered by a progressively thinner layer of char. Some perforations may also be completely uncovered. Nevertheless, the presence of concentrated char inside the inlet end 120a of the conduit 120 (thus, inside the discharge opening 112) will prevent the primary air from flowing in large quantities across the discharge opening 112. Thus, unlike existing grates, the location where the char bums will not generate unused primary air that would only increase the excess air and lower the overall thermal efficiency.

[0057] Still, providing the char under the bed floor 102 in a concentrated manner will maximize the heat. The char will also consume a good amount of the oxygen from the primary air. The heat generated therein will be transferred to the bed floor 102 through radiant heat and also some convective heat. The primary air coming through the perforations of the bed floor 102 and from the discharge opening 112 will already be pre- heated to some extent.

[0058] In the example shown in FIGS. 2 to 5, the grate 100 is designed so that the overall primary air feed passageway of the first region will be about 6% of the primary air feed. The second, third, fourth and fifth regions will provide about 19%, 25%, 30% and 16% of the total primary air feed, respectively. The balance (4%) will come through the discharge opening 112. Other designs, configurations and proportions are possible as well.

[0059] FIG. 6 is a side view illustrating another example of a grate incorporating the proposed concept and for use in a heat generator such as the heat generator 10 shown in FIG. 1. This grate referred to as the grate 200. It includes a perforated bed floor 202 having an upper surface with a rim 204 around its periphery. The perforated bed floor 202 is generally rectangular in shape, as best shown in FIGS. 7 and 8. FIGS. 7 and 8 are a top isometric view and a bottom isometric view of the grate 200, respectively. The perforated bed floor 202 is made using a plurality of flat panels 206 that are welded together. Variants are also possible. The grate 200 has a loading area 208.

[0060] The grate 200 includes two discharge openings 210 and two char-receiving conduits 212 with bottom perforations. This feature can also be implemented on another kind of grate, such as the grate 100. The discharge openings 210 of the grate 200 are disposed side-by-side and are located adjacent to the rim 204 of the perforated bed floor 202.

[0061] Still, one can design the grate 200 with only one discharge opening 210 and only one char- receiving conduit 212. Other possible configurations and arrangements include using more than two discharge openings 210 and more than two char- receiving conduits 212, and/or using a grate having two or more spaced- apart loading areas converging towards one or more discharge openings 210. Still, one can use two or more char- receiving conduits 212 with only one discharge opening 210. Many other combinations are possible as well.

[0062] Also shown in FIGS. 6 and 8 are examples of brackets 220 for attaching the char-receiving conduits 212 underneath the bed floor 202 of the grate 200. Variants are also possible.

[0063] As can be appreciated, the proposed concept provides a way to better control the amount of primary air when generating heat energy using a granular fuel material fed on a grate. It also provides a way of designing a grate that is very compact. This grate can improve the overall thermal efficiency of a heat generator.

[0064] The present detailed description and the appended figures are meant to be exemplary only. A skilled person will recognize that variants can be made in light of a review of the present disclosure without departing from the proposed concept.

Claims

1. A substantially horizontally-disposed grate for burning a granular fuel material to be fed onto a loading area of the grate while an air feed is coming from below the grate, the grate including:

   a perforated bed floor having a downwardly-sloping upper surface converging towards a discharge opening where char is concentrated as the granular fuel material is burned during op-

eration; and
an elongated and bottom-perforated char-receiving conduit positioned immediately under the bed floor, the char-receiving conduit having an inlet end positioned under the discharge opening, and an outlet end that is opposite the inlet end, the char-receiving conduit downwardly sloping between the inlet end and the outlet end.

2. The grate as defined in claim 1, wherein the bed floor has at least two regions with distinct perforation patterns, a first region among the at least two regions being adjacent to the periphery of the upper surface and including the loading area, and a second region among the at least two regions being generally located between the first region and the discharge opening.

3. The grate as defined in claim 2, wherein the perforation pattern of one of the at least two regions creates a larger overall primary air feed passageway than the perforation pattern of another of the at least two regions.

4. The grate as defined in any one of claims 1 to 3, wherein the discharge opening is located within the periphery of the upper surface.

5. The grate as defined in claim 4, wherein the discharge opening is offset with reference to a geometric center of the upper surface.

6. The grate as defined in any one of claims 1 to 5, wherein the upper surface of the bed floor is generally conical in shape.

7. The grate as defined in any one of claims 1 to 6, wherein the periphery of the upper surface is generally circular in shape.

8. The grate as defined in any one of claims 1 to 6, wherein the periphery of the upper surface is generally rectangular in shape.

9. The grate as defined in any one of claims 1 to 8, wherein the char-receiving conduit is substantially tubular in shape.

10. The grate as defined in any one of claim 1 to 8, wherein the char-receiving conduit is substantially rectangular in shape.

11. The grate as defined in any one of claims 1 to 10, wherein the bed floor has a vertical plane of symmetry and the char-receiving conduit generally has a longitudinal axis that extends substantially parallel to the plane of symmetry.

12. The grate as defined in any one of claims 1 to 11, wherein the char-receiving conduit is supported under the bed floor using at least one bracket.

13. The grate as defined in any one of claims 1 to 12, further including at least one additional discharge opening and at least one additional char-receiving conduit, one for each additional discharge opening, the discharge openings being spaced apart from one another and the char-receiving conduits extending substantially parallel to one another.

14. The grate as defined in any one of claims 1 to 13, wherein the conduit has a cross-sectional area that is about 2 to 4% of an area of the upper surface of the bed floor.

15. The grate as defined in any one of claims 1 to 14, wherein the upper surface has an average slope between 5 and 25 degrees with reference to the horizontal.

16. The grate as defined in any one of claims 1 to 15, wherein the char-receiving conduit has an average slope between 5 and 20 degrees with reference to the horizontal.

17. A method of burning a granular fuel material, the method including the concurrent steps of:

loading the granular fuel material in a loading area of a substantially horizontally-disposed bed floor;
vibrating the bed floor to move the granular fuel material from the loading area towards a discharge opening located away from and vertically below the loading area;
feeding primary air across the bed floor, the primary air coming from a bottom side and passing through a multitude of spaced-apart perforations made in the bed floor;
drying, mostly by radiation heat, the granular fuel material immediately after the granular fuel material is loaded onto the bed floor;
transforming, by pyrolysis, the dried granular fuel material into volatile compounds and char, and generating heat above the bed floor;
collecting and concentrating the char passing through the discharge opening into an elongated chamber extending substantially horizontally underneath the bed floor; and
generating heat by burning the char inside the chamber as the char is moved from the discharge opening towards an outlet end of the chamber by the vibrations of the bed floor.

18. The method as defined in claim 17, wherein during continuous operation, the perforations of the bed floor are constantly covered by some of the granular fuel material.

19. The method as defined in claim 17 or 18, wherein feeding the primary air across the bed floor includes passing the primary air through at least two different sets of perforations in the bed floor, a first set among the at least two sets providing less air across the bed floor than a second among the at least two sets.

20. The method as defined in any one of claims 17 to 19, wherein feeding the primary air across the bed floor includes passing some of the primary air through the discharge opening while the discharge opening is filled with some of the char.

21. The method as defined in any one of claims 17 to 20, further including:

feeding secondary air above the bed floor to complete the combustion of the volatile compounds.

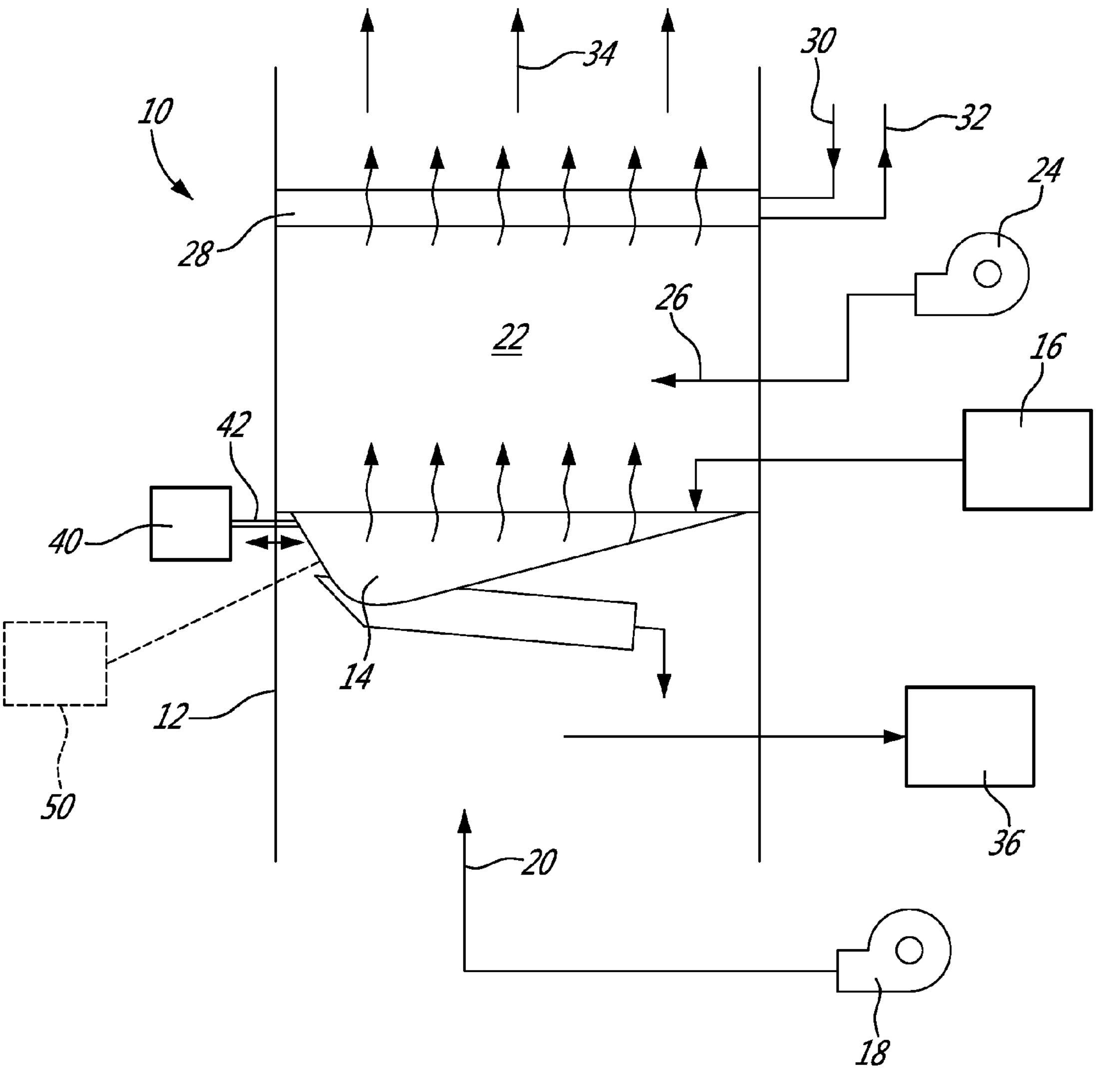


FIG. 1

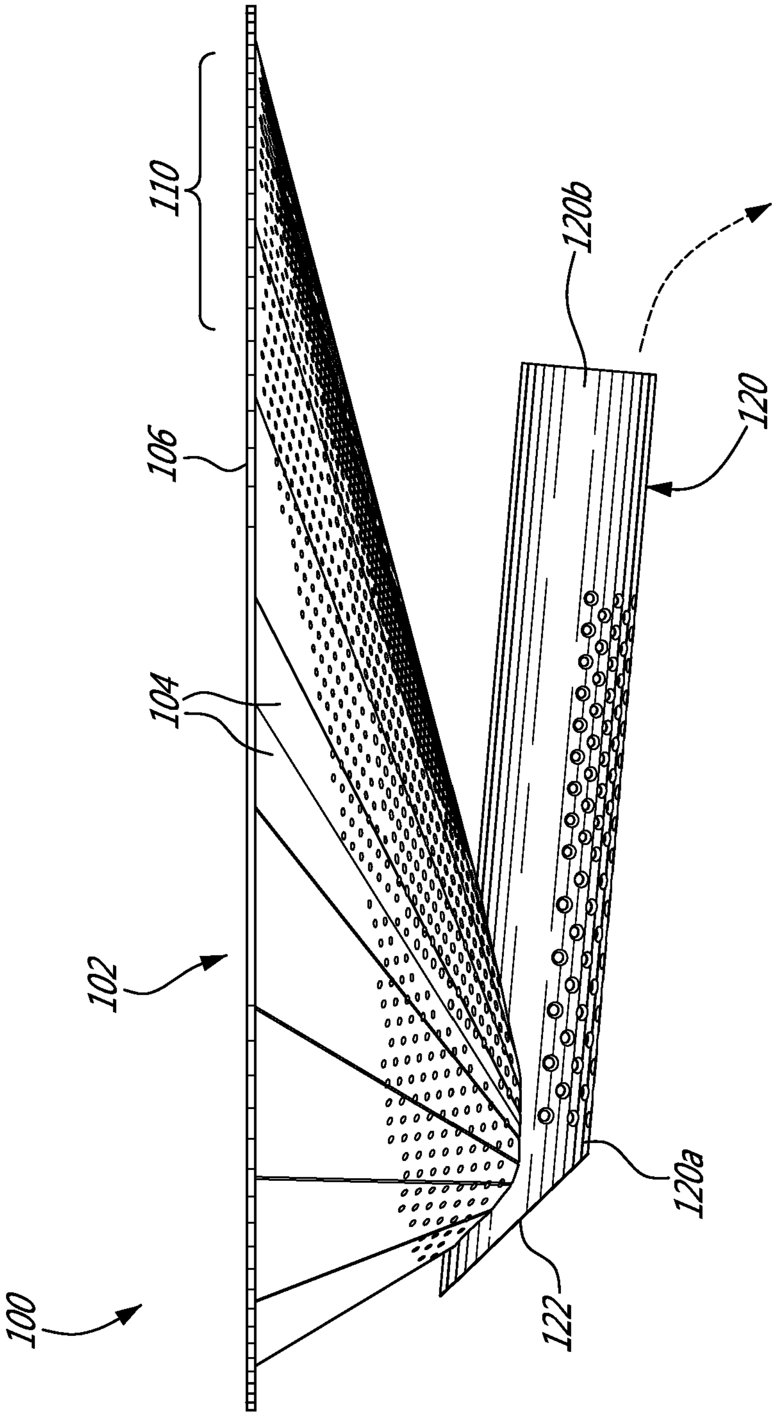
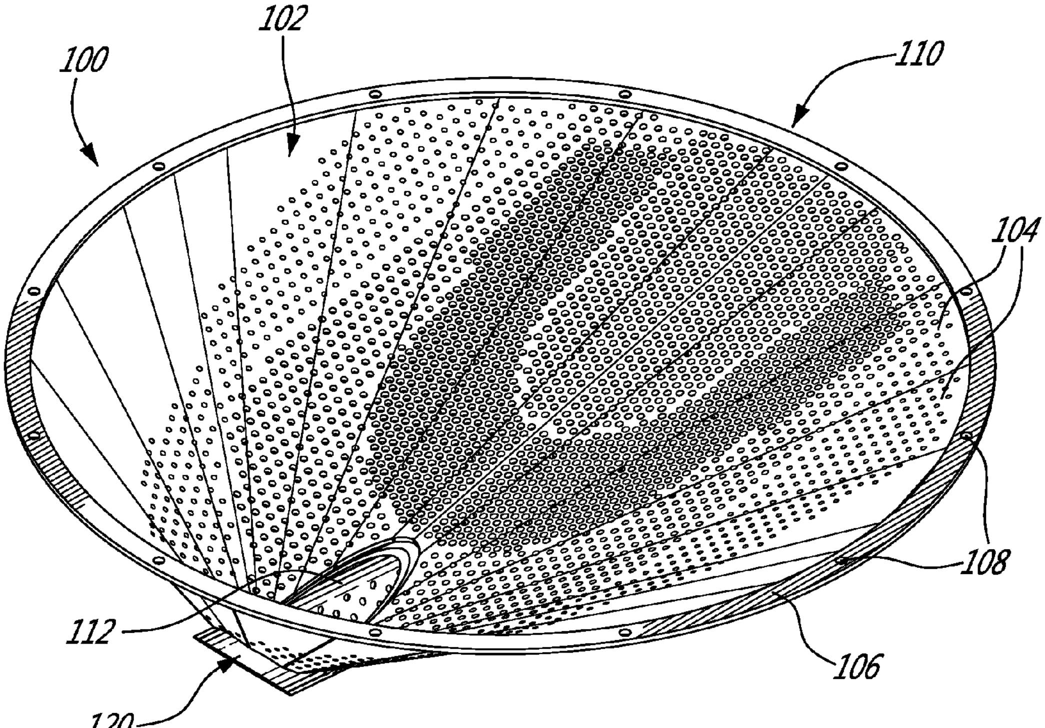


FIG. 2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110
104
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112
106
120

FIG. 3

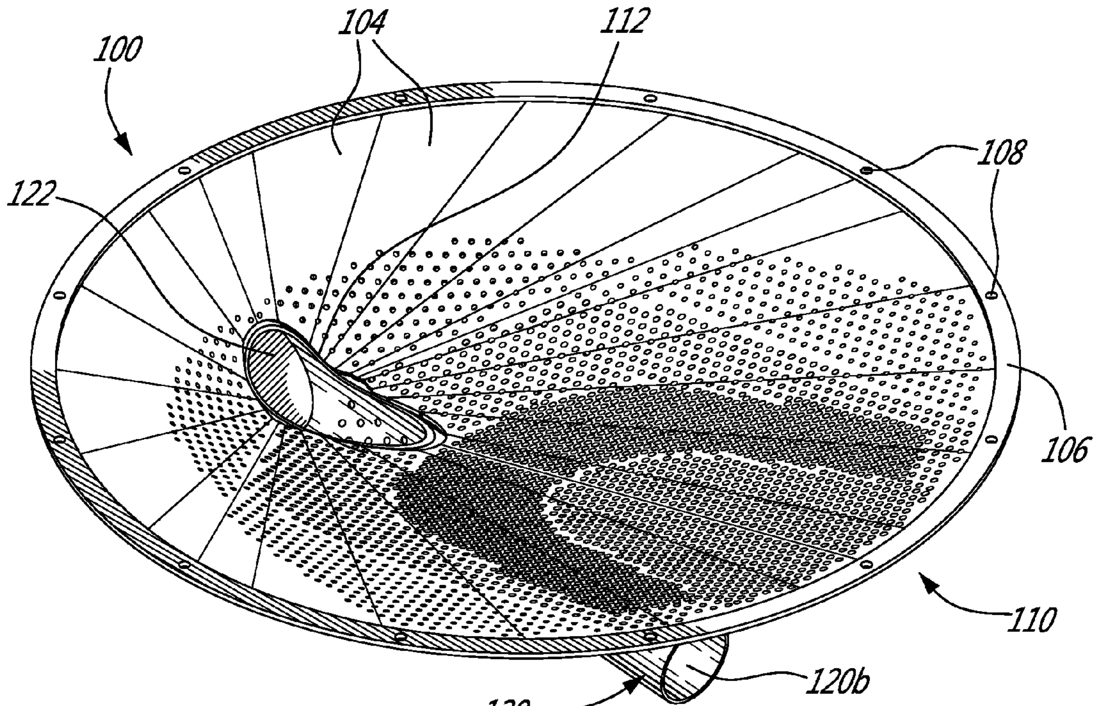
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FIG. 4

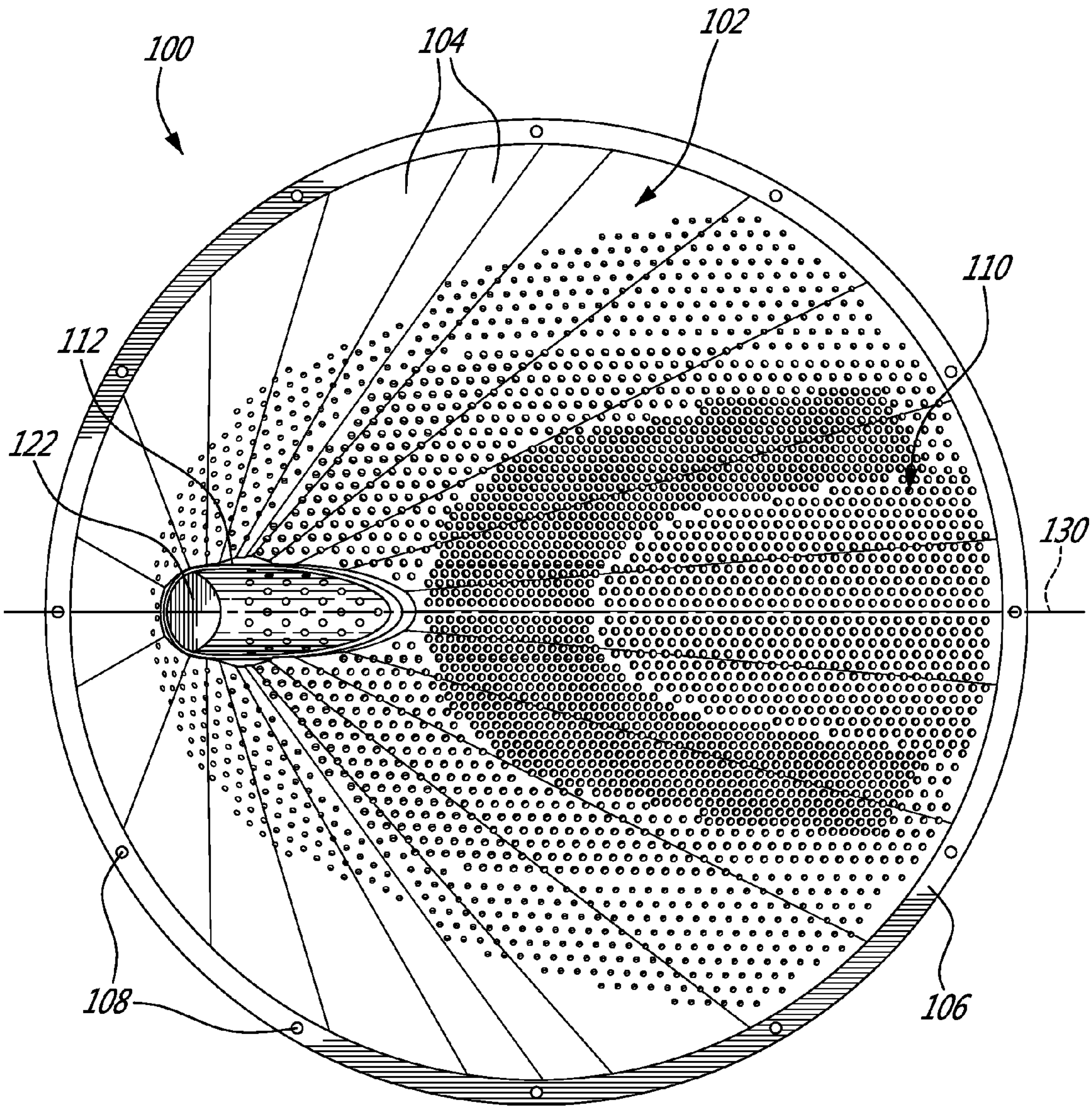

FIG. 5

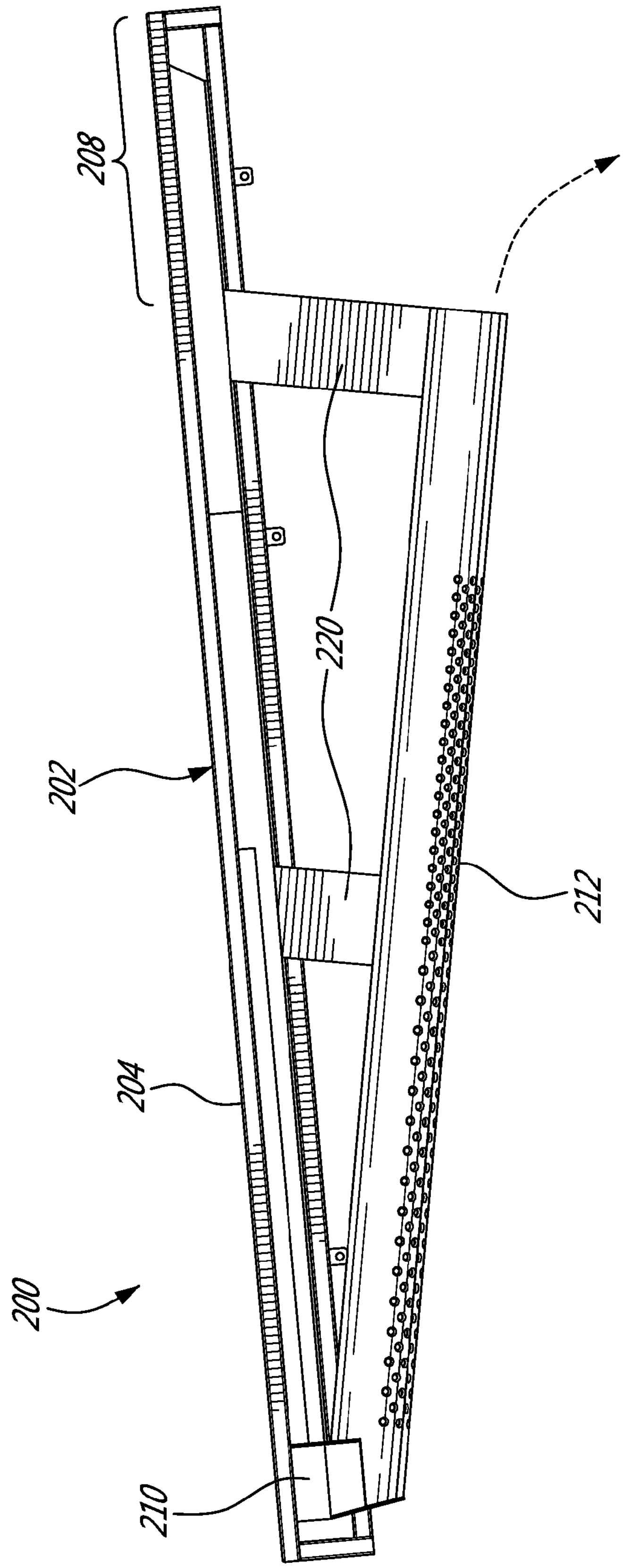

FIG-6

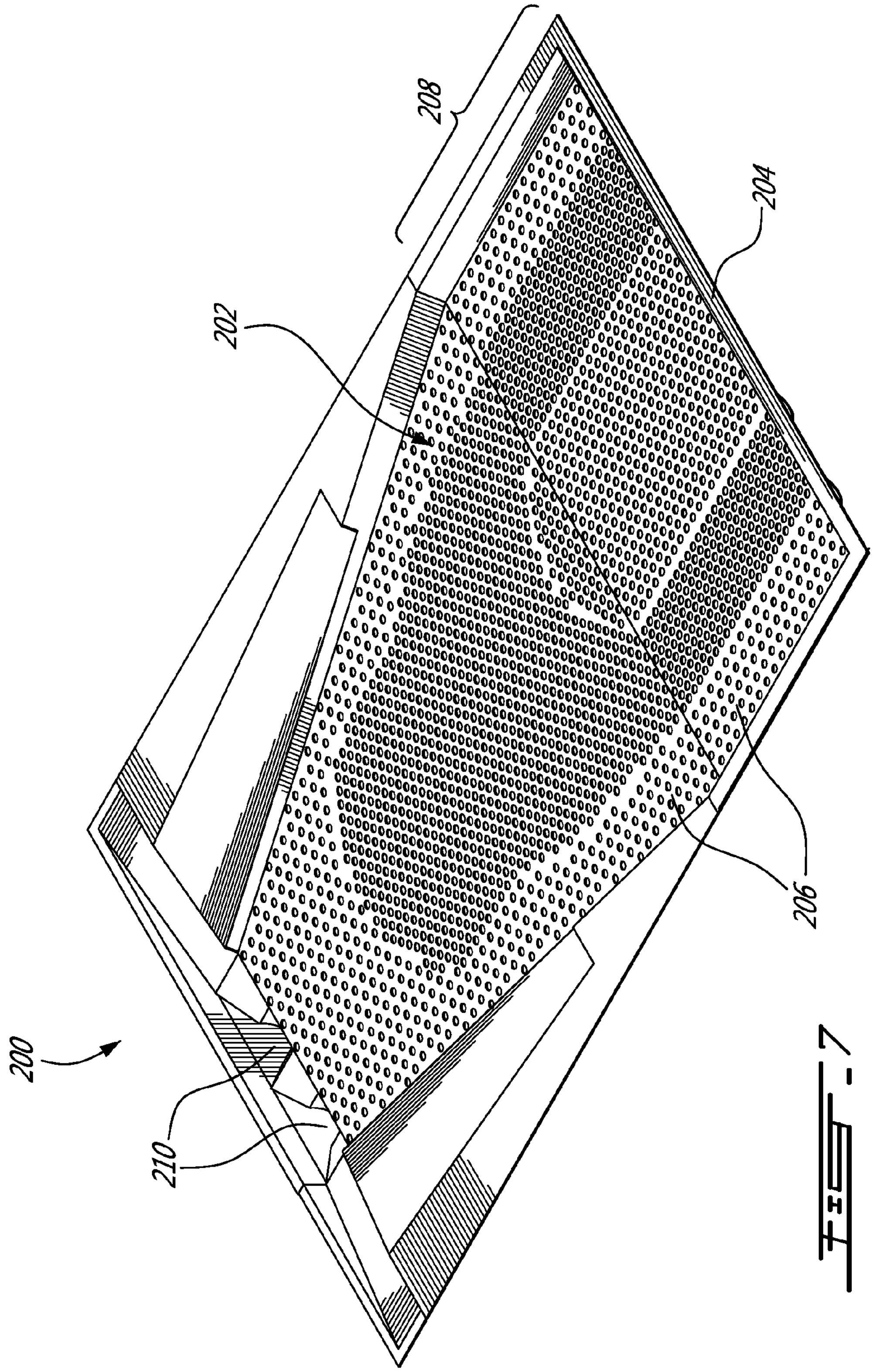

FIG - 7

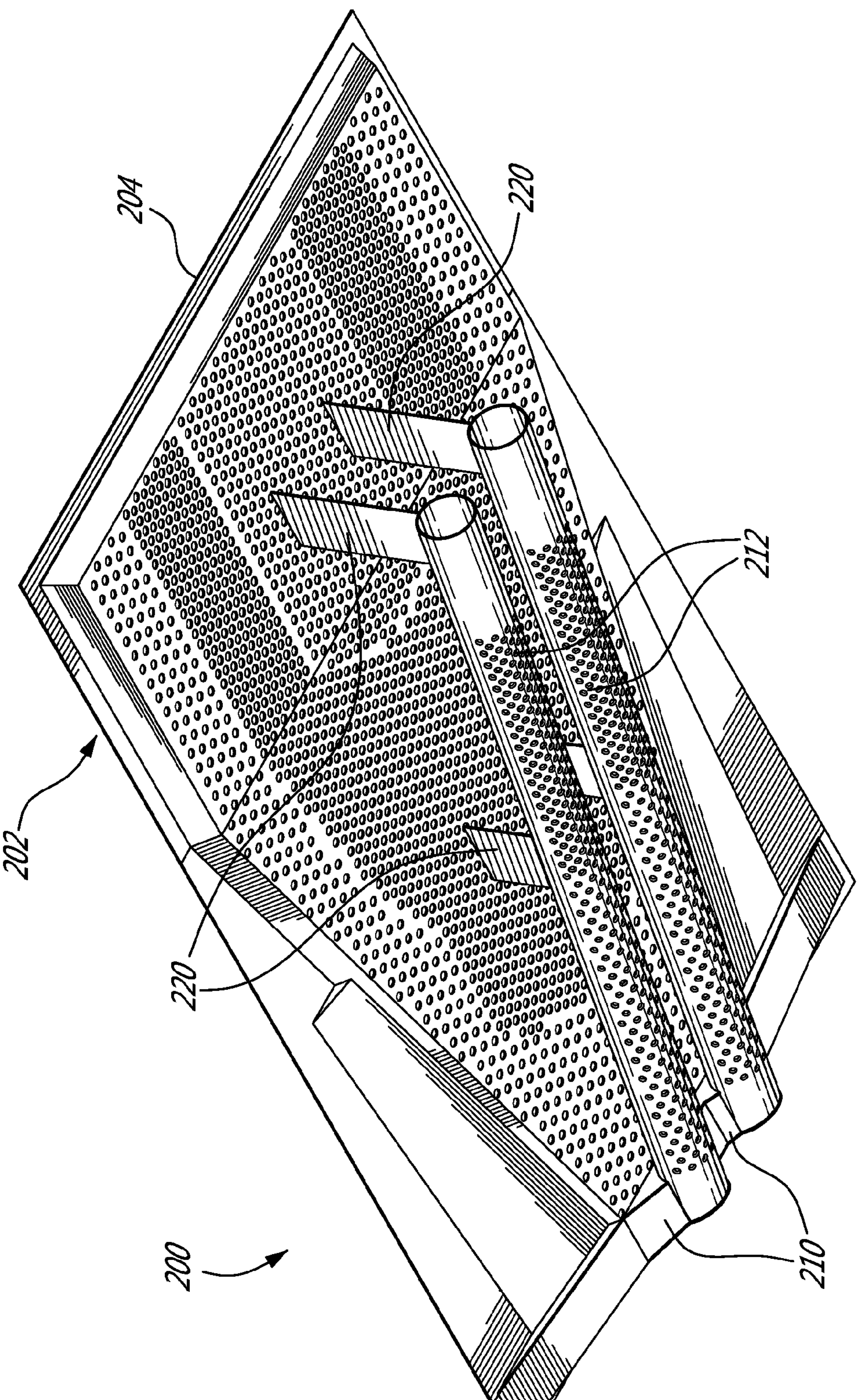

FIG. 8