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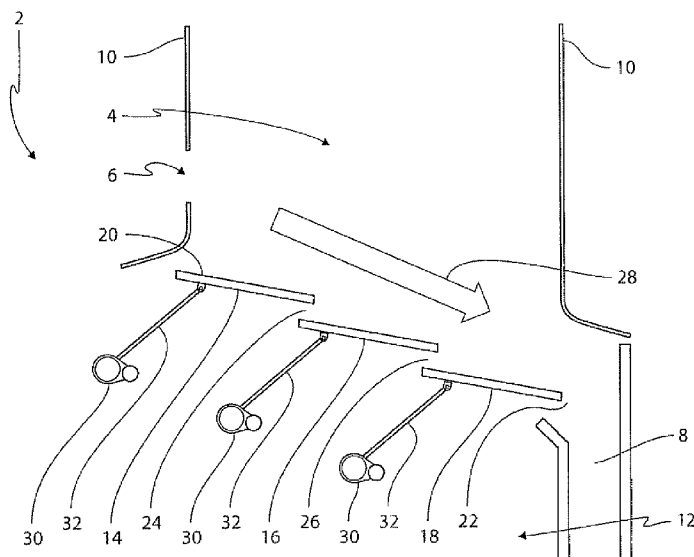


FIG. 1

(57) Abstract: The invention pertains to a combustion grate assembly for a combustion plant, the grate assembly comprising a cascade of inclined grates, the grates being mounted with a step between the grates so that fuel is able to move from one grate in the cascade down to the next grate in the cascade under the influence of the force of gravity, and wherein each grate is connected to a vibrating system for vibrating the grates and thereby advancing the fuel from a fuel inlet zone on the first grate in the cascade to a bottom ash discharge zone on the last grate in the cascade. Each grate may be connected to an individual vibrating system for vibrating the grates independently of each other. The invention also pertains to a method of combusting biomass or other fuel.



VIBRATING GRATE STOKER

TECHNICAL FIELD

The present invention pertains to combustion grate assembly of vibrating grates for a combustion plant, a combustion plant comprising such a grate assembly, and a method of combusting biomass. The present invention is especially well suited for combusting refuse derived fuel (RDF), shredded demolition wood and other solid fuels.

BACKGROUND OF THE INVENTION

In industrial combustion or boiler plants it is known to apply either a vibrating grate stoker or a reciprocating grate stoker.

Reciprocating grate stokers have been in existence for many years and is a very popular form for burning a wide variety of waste fuels, such as waste building material, industrial waste and/or domestic household waste in order to generate electrical power. The reciprocating grate stokers usually consist of an inclined air-cooled or water-cooled reciprocating combustion grate (briefly as reciprocating combustion grate), which enables the fuel to move forward towards the ash discharge end of it more easily. The reciprocating combustion grate itself consists of a fixed combustion grate and a movable combustion grate. The fixed combustion grate and movable combustion grate are arranged such that the individual grate bars interval each other and are piled up together. The movable combustion grate will undertake a reciprocating motion through for example a hydraulic transmission. Hereby even very non-uniform fuel material may be separated and evenly distributed over the grate. The reciprocating motion forces the fuel to move uniformly down the grate and to discharge burned-out ash regularly. One example of such a reciprocating grate stoker is shown in EP 0 966 635, where a stepped grate assembly is applied.

Vibrating grate stokers have also been known for years, and are usually used in power and/or district heating plants. The vibrating grate stokers usually comprise an inclined or horizontal water-cooled grate consisting of two or four panels that are mounted on leaf springs and vibrated in pairs in counter phase in order to balance external forces. Hereby the fuel moves from the feeding inlet adjacent to the top of the grate towards an outlet adjacent to the bottom of it, where ash is discharged. One example of a vibrating grate stoker is shown in US 6,220,190.

A problem with this known type of vibrating grate stokers is that the combustion of the fuel is not optimized at each stage, i.e. fuel entering the grate is vibrated in the same way as the fuel that is almost burned out at the final stage before being discharged as bottom ash.

SUMMARY OF THE INVENTION

It is thus an object of the present invention to provide a vibrating grate assembly wherein it is possible to provide a more efficient and more complete combustion of the fuel.

It is furthermore an object of the present invention to provide a combustion or boiler plant with a more flexible and efficient vibrating grate assembly.

According to the present invention, the above-mentioned and other objects are fulfilled by a first aspect of the invention pertaining to a combustion grate assembly for a combustion plant, the grate assembly comprising a cascade of inclined grates, the grates being mounted with a step between the grates such that fuel is able to move from one grate in the cascade to the next grate in the cascade under the influence of the force of gravity, and wherein each grate is connected to a vibrating system for vibrating the grates and thereby advancing the fuel from a fuel inlet zone on the first grate in the cascade to a bottom ash discharge zone on the last grate in the cascade.

The fuel used is typically of a rather homogeneous nature, and may for example be biomass, such as shredded straw wood in the form of chips or wood pellets. Generally, vibration grates are especially suitable for combusting this kind of fuel, as well as refuse derived fuel (RDF). RDF is also known as solid recovered fuel or specified recovered fuel (SRF), and is a fuel produced by shredding and dehydrating solid waste, for example with a so called waste converter technology. RDF consists largely of combustible components of municipal and/or industrial waste such as plastics, packaging materials, and biodegradable waste. SRF can be distinguished from RDF in the fact that it is produced to reach a standard such as CEN/343 ANAS. The fuel can also be wood chips generated from wood harvested from demolition of buildings or other constructions containing wood.

Investigations performed by the applicant have shown that a more complete and efficient combustion of the fuel can be achieved if at least two vibrating grates with a step between them are used rather than one grate. When the fuel is deposited on the inlet zone on the first grate, which is adjacent to the uppermost part of it, it is ignited and advances downwardly due to the vibrations of the first grate until it reaches the bottom of it and drops down onto the second grate, due to the step between the grates. Hereby the fuel is overturned and/or broken into smaller pieces and burned-out slag and ashes are separated from the yet un-combusted part of the fuel thus increasing the access of combustion air to the individual parts of the yet un-combusted fuel. This causes a more complete combustion of the fuel and therefore increases the efficiency of it.

According to a preferred embodiment of the first aspect of the invention, each grate may be connected to an individual vibrating system for vibrating the grates independently of each other and thereby advancing the fuel from a fuel inlet zone on the first grate in the cascade to a slag discharge zone on the last grate in the cascade. In addition to the advantages mentioned above it is hereby achieved that the vibrations of the grates may be individually adapted to the degree the fuel is combusted. For example the first grate is vibrated in a manner that optimizes the stoking of newly ignited fuel, while the last grate may be vibrated in a way that optimizes combustion of the remaining coal in the fuel. This leads to a more even combustion and facilitates a better control of the energy emission generated by the combustion. The distribution of the fuel, drying and pyrolysis is also easier to control by vibrating the grates independently of each other.

In a preferred embodiment the cascade comprises only two or three grates. However, the number of grates in the cascade may conveniently be chosen in dependence of the physical requirements, i.e. in dependence of the size of the total grate length and height from fuel inlet to bottom ash discharge

In many vibrating grate systems often excessive vibration is coupled to the boiler and the surrounding structure. This occurs, particularly when the grate is not effectively counter-balanced. Hence, in a preferred embodiment of the first aspect of the invention each grate comprises an even number of panels stretching longitudinally along the grate in the direction of advancement of the fuel, and wherein said vibration of each grate is accomplished by a vibration of an equal number of panels in counter phase to

each other. Hereby the vibrations are to a large extent counter balanced and thus causes reduced coupling to the surroundings, and thereby also to reduced noise, and alleviates the need to use additional (and spacious) counter balance members.

According to an embodiment of the first aspect of the invention, the grates are vibrated intermittently, i.e. in sequences of vibrations followed by pauses. Hereby is achieved a longer retention time of the fuel and thereby a better combustion as well as reduced noise originating from the vibrations of the grate(s) and surrounding structures

According to an embodiment of the first aspect of the invention, the time span between the pauses may be 18–240 times the time span at which the grates are vibrated. Hereby is obtained an optimal combustion of the fuel, especially the kind of fuel mentioned above.

In a preferred embodiment of the first aspect of the invention, at least one of the grates are vibrated at a frequency of approximately 6 Hz–approximately 9 Hz.

In a preferred embodiment of a combustion grate assembly according to the first aspect of the invention, the last grate is vibrated at a lower frequency or at a shorter time than the first grate. Investigations have surprisingly shown that this causes a more complete and better combustion of the coal in the remaining un-combusted parts of the fuel.

In yet a preferred embodiment of a combustion grate assembly according to the first aspect of the invention, the pauses between the vibrations of the last grate are longer than the pauses between the vibrations of the first grate. Hereby is achieved a longer retention time of the fuel within the "combustion zone" of the grate assembly, and thereby a better combustion of the coal within the remaining un-combusted fuel that has reached the second grate.

In yet a preferred embodiment of a combustion grate assembly according to the first aspect of the invention, the amplitude of vibration of the grates is less than 15 mm.

Advantageously, the grates according to an embodiment of the first aspect of the invention are mounted on a frame by leaf springs.

In a preferred embodiment of the first aspect of the invention, the grates are water-cooled panels. The water-cooled tube panels are in turn connected to a water-cooling system. This cooling of the grates causes reduced wear, and enables an effective control of the ignition and combustion of the fuel that is fed into the grate.

In a further embodiment of a first aspect of the invention, the grates may comprise replaceable grate wearing bars with apertures provided therein in order to supply combustion air to the fuel to be placed on the grates. The apertures are preferably connected to a number of air units positioned under the grates. These air units are individually connected to an air supply in order to supply combustion air to the apertures.

According to a preferred embodiment of the first aspect of the invention, the grates are inclined by an angle of between 2 degrees and 30 degrees in relation to the horizontal plane, preferably between 4 degrees and 10 degrees in relation to the horizontal plane, such as for example 6 degrees in relation to horizontal. Hereby is achieved a good compensation for possible non-uniform movement of the fuel and ashes and slags. Investigations have shown that if a grate inclination of 6 degrees or more is used in combination with water-cooled grate panels, then the cooling water may be implemented as an integral part of a pressurized boiler water system.

In order to provide a good tradeoff between the building height and associated costs overturning and breakdown of the partly combusted fuel, the step between the grates may in a preferred embodiment of the first aspect of the invention be between 10 cm and 80 cm, preferably between 30 cm and 60 cm. Investigations have shown that good results are achieved with a step of 40 cm.

The above mentioned and further objects are fulfilled by a second aspect of the invention pertaining to a combustion grate assembly for a combustion plant, the grate assembly comprising a cascade of inclined or horizontal grates, the grates being mounted such that fuel is able to move from one grate in the cascade to the next grate in the cascade, wherein each grate is connected to an individual vibrating system for vibrating the grates independently of each other and thereby advancing the fuel from a fuel inlet zone on the first grate in the cascade to a slag discharge zone on the last grate in the cascade.

Hereby is achieved that the vibrations, e.g. vibration time, amplitude or frequency, of the grates may be individually adapted to the degree the fuel is combusted. For example the first grate is vibrated in a manner that optimizes the stoking of newly ignited fuel, while the last grate may be vibrated in a way that optimizes combustion of the remaining coal in the fuel. This leads to a more even combustion and facilitates a better control of the energy release generated by the combustion. The distribution of the fuel, drying and pyrolysis is also easier to control by vibrating the grates independently of each other.

According to an embodiment of the second aspect of the invention, each grate comprises an even number of panels stretching longitudinally along the grate in the direction of advancement of the fuel, and wherein said vibration of each grate is accomplished by vibration of an equal number of panels in counter phase to each other.

According to an embodiment of the second aspect of the invention, the grates are vibrated intermittently, i.e. in sequences of vibrations followed by pauses.

According to an embodiment of the second aspect of the invention, the time span between the pauses is 18–240 times the time span at which the grates are vibrated.

According to an embodiment of the second aspect of the invention, at least one of the grates are vibrated at a frequency of approximately 6 Hz–approximately 9 Hz.

According to an embodiment of the second aspect of the invention, the last grate is vibrated at a lower frequency and/or a shorter time than the first grate.

In yet a preferred embodiment of a combustion grate assembly according to the second aspect of the invention, the pauses between the vibrations of the last grate are longer than the pauses between the vibrations of the first grate.

According to an embodiment of the second aspect of the invention, the amplitude of vibration of the grates is less than 15 mm.

According to an embodiment of the second aspect of the invention, the grates are mounted with a step between the grates such that fuel is able to move from one grate

in the cascade to the next grate in the cascade under the influence of the force of gravity.

According to an embodiment of the second aspect of the invention, the step between the grates is between 10 cm and 80 cm, preferably between 30 cm and 60 cm, such as 40 cm.

According to an embodiment of the second aspect of the invention, the grates are mounted on a frame by leaf springs.

According to an embodiment of the second aspect of the invention, the grates are water-cooled panels. This may be achieved as explained above with reference to the discussion of embodiments of the first aspect of the invention.

According to an embodiment of the second aspect of the invention, the grates comprises grate bars with apertures provided therein in order to supply combustion air to the fuel to be placed on the grates. This may be achieved as explained above with reference to the discussion of embodiments of the first aspect of the invention.

According to an embodiment of the second aspect of the invention, the grates are inclined by an angle of between 2 degrees and 30 degrees in relation to the horizontal plane, preferably between 4 degrees and 10 degrees in relation to the horizontal plane, such as preferably 6 degrees in relation to the horizontal plane.

The above mentioned and further objects are achieved by a third aspect of the invention pertaining to a combustion plant comprising: A combustion chamber having a fuel inlet and a slag and ash discharge chute, wherein the combustion chamber further comprises a grate assembly according to any of the two aspects discussed above or embodiments thereof (also discussed above). Said grate assembly is positioned within the combustion chamber between the fuel inlet and the slag and ash discharge chute, so that fuel feed through the fuel inlet is deposited on the fuel inlet zone on the first grate in the cascade and slag discharged from the slag discharge zone on the last grate in the cascade is deposited in the slag and ash discharge chute.

The above mentioned and further objects are furthermore achieved by a fourth aspect of the invention, pertaining to a method of combusting biomass or other types of fuel, the method comprising the steps of:

- depositing fuel on a fuel inlet zone on a first grate of a grate assembly, said grate assembly comprising a cascade of inclined grates, the grates being mounted with a step between the grates so that the fuel moves from one grate in the cascade to the next grate in the cascade under the influence of the force of gravity,
- igniting the fuel,
- advancing the fuel from the fuel inlet zone on the first grate in the cascade to a slag discharge zone on the last grate in the cascade by vibrating the grates, and
- discharging slag and ashes into a slag and ash discharge chute.

According to an embodiment of the fourth aspect of the invention, the method further comprises the step of vibrating the grates independently of each other.

According to an embodiment of the fourth aspect of the invention, the method further comprises the step of vibrating the grates intermittently, i.e. in sequences of vibrations followed by pauses.

According to an embodiment of the fourth aspect of the invention, the time span between the pauses are 18–240 times the time span at which the grates are vibrated.

According to an embodiment of the fourth aspect of the invention, at least one of the grates is vibrated at a frequency of approximately 6 Hz–approximately 9 Hz.

According to an embodiment of the fourth aspect of the invention, the method further comprises the step of vibrating the last grate at a lower frequency or at a shorter time than the first grate.

In yet a preferred embodiment of a method according to the fourth aspect of the invention, the pauses between the vibrations of the last grate are longer than the pauses between the vibrations of the first grate.

According to an embodiment of the fourth aspect of the invention, the amplitude of vibration of the grates is less than 15 mm.

The above mentioned and further objects are furthermore achieved by a fifth aspect of the invention, pertaining to a method combusting biomass or other types of fuel, the method comprising the steps of:

- depositing fuel on a fuel inlet zone on a first grate of a grate assembly, said grate assembly comprising a cascade of inclined grates, the grates being mounted such that fuel is able to move from one grate in the cascade to the next grate in the cascade, each grate being connected to an individual vibrating system for vibrating the grates,
- igniting the fuel,
- advancing the fuel from the fuel inlet zone on the first grate to a slag discharge zone on the last grate by vibrating the grates independently of each other, and
- discharging slag and ashes into a slag and ash discharge chute

According to an embodiment of the fifth aspect of the invention, the method further comprises the step of vibrating the grates intermittently, i.e. in sequences of vibrations followed by pauses.

According to an embodiment of the fifth aspect of the invention, the time span between the pauses are 18–240 times the time span at which the grates are vibrated.

According to an embodiment of the fifth aspect of the invention, at least one of the grates is vibrated at a frequency of approximately 6 Hz—approximately 9 Hz.

According to an embodiment of the fifth aspect of the invention, the method further comprises the step of vibrating the last grate at a lower frequency or at a shorter time than the first grate.

In yet a preferred embodiment of method according to the fifth aspect of the invention, the pauses between the vibrations of the last grate are longer than the pauses between the vibrations of the first grate.

According to an embodiment of the fifth aspect of the invention, the amplitude of vibration of the grates is less than 15 mm.

According to an embodiment of the fifth aspect of the invention, the grates are mounted with a step between the grates so that fuel is able to move from one grate in the cascade to the next grate in the cascade under the influence of the force of gravity.

BREIF DESCRIPTION OF THE DRAWINGS

A further understanding of the nature and advantages of the present invention may be realized by reference to the remaining portions of the specification and the drawings. In the following, preferred embodiments of the invention is explained in more detail with reference to the drawings, wherein

Fig. 1 schematically illustrates a part of an embodiment of a combustion plant,

Fig. 2 schematically illustrates a side view of a combustion grate,

Fig. 3 schematically illustrates a perspective view of a combustion grate,

Fig. 4 schematically illustrates a part of another embodiment of a combustion plant,

Fig. 5 shows a flow diagram of an embodiment of a method of combusting biomass,
and

Fig. 6 shows a flow diagram of an embodiment of another method of combusting biomass.

DETAILED DESCRIPTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. The invention may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like reference numerals refer to like elements throughout. Like elements will, thus, not be described in detail with respect to the description of each figure.

Fig. 1 schematically illustrates a part of an embodiment of a combustion plant 2 comprising a combustion chamber 4 having a fuel inlet 6 and a slag and ash discharge chute 8. The combustion chamber 4 is bounded in part by the furnace walls 10. In the combustion chamber 4 a grate assembly 12 is installed and positioned between the fuel inlet 6 and the slag and ash discharge chute 8. The grate assembly 12 comprises in the illustrated embodiment a cascade of three grates 14, 16 and 18, so that fuel feed through the fuel inlet 6 is deposited on the fuel inlet zone 20 on a first grate and

slag is discharged from a slag discharge zone 22 on the third grate 18 and deposited in the slag and ash discharge chute 8.

The illustrated grates 14, 16, 18 are inclined in relation to horizontal and mounted with a step 24 and 26 between the grates 14, 16, 18 such that fuel is able to move from the first grate 14 to the second grate 16, and from the second grate 16 to the third grate 18 under the influence of the force of gravity. The fuel moves generally in the direction of the arrow 28. Each grate 14, 16, 18 is connected to a vibrating system for vibrating the grates 14, 16, 18 and thereby advancing the fuel from the fuel inlet zone 20 on the first grate 14 in the cascade to the slag discharge zone 22 on the third grate 18 (the last grate in the cascade).

The fuel used is typically of a rather homogeneous nature, and may for example be biomass, such as shredded straw, wood in the form of chips or wood pellets. Generally, vibration grates are especially suitable for combusting this kind of fuel, as well as refuse derived fuel (RDF). RDF is also known as solid recovered fuel or specified recovered fuel (SRF), and is a fuel produced by shredding and dehydrating solid waste, for example with a so called waste converter technology. RDF consists largely of combustible components of municipal and/or industrial waste such as plastics, packaging material and biodegradable waste. SRF can be distinguished from RDF in the fact that it is produced to reach a standard such as CEN/343 ANAS. The fuel can also be wood chips generated from wood harvested from demolition of buildings or other constructions containing wood.

When the fuel is deposited on the inlet zone 20 on the first grate 14, which is adjacent to the uppermost part of it (14), the fuel is ignited and advances downwardly generally in a direction along the arrow 28 due to the vibrations of the first grate 14 until it reaches the bottom of it (14) and drops down onto the second grate 16, due to the step 24 between the grates 14 and 16. Hereby the fuel is broken into smaller pieces and burned-out slag and ashes are separated from the yet un-combusted part of the fuel, thus increasing the access of combustion air to the individual parts of the yet un-combusted fuel. When the fuel reaches the lowest part of the second grate 16 it drops down onto the third grate 18 due to the step 26. This causes a more complete combustion of the fuel and therefore increases the efficiency of the grate assembly 12. In the illustrated embodiment there is shown two steps 24, 26, but in other embodiments

it could comprise only two grates with one step between them, or a larger number of grates having an associated larger numbers of steps between them.

In the illustrated embodiment, each grate 14, 16, 18 is be connected to an individual vibrating system for vibrating the grates 14, 16, 18 independently of each other and thereby advancing the fuel from the fuel inlet zone 20 on the first grate to the slag discharge zone 22 on the third grate 18. Each individual vibrating system comprises a vibration generating unit 30. Each of these vibration generating units 30 is connected to one of the grates 14, 16, 18, via a vibration beam 32.

In addition to the advantages mentioned above it is hereby achieved that the vibrations of the grates 14, 16, 18 may be individually adapted to the degree the fuel is combusted. For example the first grate 14 may be vibrated in a manner that optimizes the stoking and/or drying of newly ignited fuel, possibly partly wet fuel, while the second grate 16 may be vibrated in a way that optimizes combustion of partly combusted fuel, and the third grate 18 may be vibrated in a way that optimizes combustion of the remaining coal in the fuel. This leads to a more even combustion and facilitates a better control of the energy emission generated by the combustion. The distribution of the fuel, drying and pyrolysis is also easier to control by vibrating the grates 14, 16, 18 independently of each other. The grates 14, 16, 18 may be equipped with different types of grate bars and with different spacing between the grate bars.

Fig. 2 shows a more detailed view of the grate 14. The grates 16 and 18 comprise the same elements as illustrated in Fig. 2. The grate 14 is mounted on a number of leaf springs 34, and is connected to a vibration generating unit 30 through a vibration beam 32. The application of the leaf springs 34 works like hinges on top of carrying legs. The applied leaf springs 34 have substantially no influence on the vibrations, which are determined by the motor (vibration generating unit 30) and the vibrations start/stop substantially immediately when the motor starts/stops.

Fig. 3 shows a perspective view of a schematic illustration of an embodiment of the grate 14. In many vibrating grate systems often excessive vibration is coupled to the boiler and the surrounding structure, e.g. walls 10 of the furnace or combustion chamber 4. The walls and the grates may, however, also itself be part of the boiler. This occurs particularly when the grate(s) is not effectively counter-balanced. Hence, in a preferred embodiment each grate 14, 16, 18 comprises an even number of panels 36,

38, 40, 42 stretching longitudinally along the grate 14 in the direction of advancement of the fuel. Vibration of the grate 14 is accomplished by a vibration of an equal number of panels 36, 38, 40, 42 in counter phase to each other. Hereby the vibrations are to a large extent counter balanced and thus causes reduced coupling to the surroundings, and thereby also to reduced noise, and alleviates the need to use additional (and spacious) counter balance members. For example the panels 36 and 40 are vibrated in counter phase to the panels 38 and 42, or the panels 36 and 42 are vibrated in counter phase to the panels 38 and 40.

Two of the grates 14, 16, 18, are vibrated intermittently and in counterphase, i.e. in sequences of vibrations followed by pauses. Hereby is achieved a longer retention time of the fuel and thereby a better combustion as well as reduced noise originating from the vibrations of the grate(s) and surrounding structures. The time span between the pauses may be 18–240 times the time span at which the grates 14, 16, 18 are vibrated. Hereby is obtained an optimal combustion of the fuel, especially the kind of fuel mentioned above. Preferably, the grates are vibrated at a frequency of 6 Hz–9 Hz.

In a preferred embodiment the second grate 16 is vibrated at a lower frequency than the first grate 14, and the third grate 18 is preferably vibrated at a lower frequency than the second grate 16. Investigations have surprisingly shown that this causes a more complete and better combustion of the coal in the remaining un-combusted parts of the fuel.

Preferably, the pauses between the vibrations of the second grate 16 are longer than the pauses between the vibrations of the first grate 14, and the pauses between the vibrations of the third grate 18 are longer than the pauses between the vibrations of the second grate 16. Hereby is achieved a longer retention time of the fuel within the "combustion zone" of the grate assembly 12, and thereby a better combustion of the coal within the remaining un-combusted fuel. The amplitude of vibration of the grates 14, 16, 18 is preferably less than 10 mm.

The grates 14, 16, 18 may comprise grate bars (not shown) with apertures provided therein in order to supply combustion air to the fuel to be placed on the grates 14, 16, 18. The apertures are preferably connected to an air plenum unit positioned under the grates 14, 16, 18. The air plenum is connected to an air supply in order to supply combustion air to the apertures.

In a preferred embodiment of the first aspect of the invention, the grates 14, 16, 18 are water-cooled. For example a plurality of water-cooling pipes may be integrated into at least some of the grate bars. The water-cooling pipes are in turn connected to a water supply. This cooling of the grates 14, 16, 18 causes reduced wear, and enables an effective control of the drying of the fuel that is fed into the first grate 14.

The grates 14, 16, 18 are inclined by an angle of between 30 degrees and 70 degrees in relation to the horizontal plane, preferably between 40 degrees and 65 degrees in relation to the horizontal plane, such as for example 60 degrees in relation to horizontal. Hereby is achieved a good compensation for possible non-uniform movement of the fuel and ashes and slags. However, in other embodiments the angle of inclination in relation to horizontal may be different for each of the grates 14, 16, 18.

In order to provide a good tradeoff between the building height and associated costs and breakdown of the partly combusted fuel, the step 24, between the first grate 14 and the second grate 16 is between 10 cm and 80 cm, preferably between 30 cm and 60 cm. Investigations have shown that good results are achieved with a step 24 of 40 cm. The step 26 may be of the same size as the step 24, or alternatively smaller than the step 24.

Fig. 4 schematically shows an alternative embodiment of the invention, pertaining to a combustion grate 12 assembly for a combustion plant. The illustrated grate assembly 12 comprises a cascade of inclined grates: A first inclined grate 14, a second inclined grate 16, and a third inclined grate 18. The grates 14, 16, 18 are mounted such that fuel is able to move from the first grate 14 to the second grate 16 and further onto the third grate 18. Each grate 14, 16, 18 is connected to an individual vibrating system for vibrating the grates 14, 16, 18 independently of each other and thereby advancing the fuel from a fuel inlet zone 20 on the first grate 14 to a slag discharge zone 22 on the third grate 18. Each individual vibrating system comprises a vibration unit 30 that is connected to a grate 14, 16, 18 through a vibration beam 32.

Hereby is achieved that the vibrations of the grates 14, 16, 18 may be individually adapted to the degree the fuel is combusted. For example the first grate 14 is vibrated in a manner that optimizes the stoking of newly ignited fuel, while the third grate 18 may be vibrated in a way that optimizes combustion of the remaining coal in the fuel.

This leads to a more even combustion and facilitates a better control of the energy emission generated by the combustion. The distribution of the fuel, drying and pyrolysis is also easier to control by vibrating the grates 14, 16, 18 independently of each other.

Fig. 5 illustrates a flow diagram of an embodiment of a method of combusting biomass, the method comprising the steps of:

- depositing biomass on a fuel inlet zone on a first grate of a grate assembly, said grate assembly comprising a cascade of inclined grates, the grates being mounted with a step between the grates such that the biomass moves from one grate in the cascade to the next grate in the cascade under the influence of the force of gravity, as indicated by the block 44,
- igniting the biomass, as indicated by the block 46,
- advancing the biomass from the fuel inlet zone on the first grate to a slag discharge zone on the last grate by vibrating the grates, as indicated by the block 48, and
- discharging slag and ashes into a slag and ash discharge chute, as indicated by the block 50.

Fig. 6 illustrates a flow diagram of an embodiment of an alternative method of combusting biomass, the method comprising the steps of:

- depositing biomass on a fuel inlet zone on a first grate of a grate assembly, said grate assembly comprising a cascade of inclined grates, the grates being mounted such that fuel is able to move from one grate in the cascade to the next grate in the cascade, each grate being connected to an individual vibrating system for vibrating the grates, as indicated by the block 52,
- igniting the biomass, as indicated by the block 54,
- advancing the biomass from the fuel inlet zone on the first grate in the cascade to a slag discharge zone on the last grate in the cascade by vibrating the grates independently of each other, as indicated by the block 56, and
- discharging slag and ashes into a slag and ash discharge chute, as indicated by the block 58.

In the following is given a list of reference numbers that are used in the detailed description of the invention.

2	combustion plant,
4	combustion chamber,
6	fuel inlet,
8	slag and ash discharge chute,
10	furnace walls,
12	grate assembly,
14, 16, 18	grates,
20	fuel inlet zone on first grate,
22	ash and slag discharge zone on third grate,
24	step between first and second grate,
26	step between second and third grate,
28	overall direction of movement of the fuel,
30	vibration unit,
32	vibration beam,
34	leaf springs,
36–42	grate panels, and
44–58	method steps.

CLAIMS

1. A combustion grate assembly for a combustion plant, the grate assembly comprising a cascade of inclined or horizontal grates, the grates being mounted with a step between the grates so that fuel is able to move from one grate in the cascade down to the next grate in the cascade under the influence of the force of gravity, and wherein each grate is connected to a vibrating system for vibrating the grates and thereby advancing the fuel from a fuel inlet zone on the first grate in the cascade to a bottom ash discharge zone on the last grate in the cascade.

2. A combustion grate assembly according to claim 1, wherein each grate is connected to an individual vibrating system for vibrating the grates independently of each other and thereby advancing the fuel from a fuel inlet zone on the first grate in the cascade to a bottom ash discharge zone on the last grate in the cascade.

3. A combustion grate assembly according to claim 1 or 2, wherein each grate comprises an even number of panels stretching longitudinally along the grate in the direction of advancement of the fuel, and wherein said vibration of each grate is accomplished by a vibration of an equal number of panels in counter phase to each other.

4. A combustion grate assembly according to claim 1, 2, or 3, wherein the grates are vibrated intermittently, i.e. in sequences of vibrations followed by pauses.

5. A combustion grate assembly according to claim 4, wherein the time span between the pauses are 18–240 times the time span at which the grates are vibrated.

6. A combustion grate assembly according to any of the preceding claims, wherein at least one of the grates are vibrated at a frequency of 6 Hz–9 Hz.

7. A combustion grate assembly according to any of the claims 1–5, wherein the last grate is vibrated at a lower frequency than the first grate.

8. A combustion grate assembly according to any of the claims 4–7, wherein the pauses between the vibrations of the last grate are longer than the pauses between the vibrations of the first grate.

9. A combustion grate assembly according to any of the preceding claims, wherein the amplitude of vibration of the grates is less than 15 mm.

10. A combustion grate assembly according to any of the preceding claims, wherein the grates are mounted on a frame by leaf springs

11. A combustion grate assembly according to any of the preceding claims, wherein the grates comprises grate bars with apertures provided therein in order to supply combustion air to the fuel to be placed on the grates.

12. A combustion grate assembly according to any of the preceding claims, wherein the grates are water-cooled or oil-cooled panels.

13. A combustion grate assembly according to any of the preceding claims, wherein the grates are inclined by an angle of between 2 degrees and 30 degrees in relation to the horizontal plane, preferably between 4 degrees and 10 degrees in relation to the horizontal plane.

14. A combustion grate assembly according to any of the preceding claims, wherein the step between the grates is between 10 cm and 80 cm, preferably between 30 cm and 60 cm.

15. A combustion grate assembly for a combustion plant, the grate assembly comprising a cascade of inclined or horizontal grates, the grates being mounted such that fuel is able to move from one grate in the cascade to the next grate in the cascade, wherein each grate is connected to an individual vibrating system for vibrating the grates independently of each other and thereby advancing the fuel from a fuel inlet zone on the first grate in the cascade to a bottom ash discharge zone on the last grate in the cascade.

16. A combustion grate assembly according to claim 15, wherein each grate comprises an even number of panels stretching longitudinally along the grate in the direction of advancement of the fuel, and wherein said vibration of each grate is accomplished by a vibration of an equal number of panels in counter phase to each other.

17. A combustion grate assembly according to claim 15 or 16, wherein the grates are vibrated intermittently, i.e. in sequences of vibrations followed by pauses.
18. A combustion grate assembly according to claim 17, wherein the time span between the pauses are 18–240 times the time span at which the grates are vibrated.
19. A combustion grate assembly according to any of the claims 15–18, wherein at least some of the grates are vibrated at a frequency of 6 Hz–9 Hz.
20. A combustion grate assembly according to any of the claims 15–19, wherein the last grate in the cascade is vibrated at a lower frequency than the first grate in the cascade.
21. A combustion grate assembly according to any of the claims 17–20, wherein the pauses between the vibrations of the last grate are longer than the pauses between the vibrations of the first grate.
22. A combustion grate assembly according to any of the claims 15–21, wherein the amplitude of vibration of the grates is less than 15 mm.
23. A combustion grate assembly according to any of the claims 15–22, wherein the grates are mounted with a step between the grates such that fuel is able to move from the one grate in the cascade to the next grate in the cascade under the influence of the force of gravity.
24. A combustion grate assembly according to claim 23, wherein the step between the grates is between 10 cm and 80 cm, preferably between 30 cm and 60 cm.
25. A combustion grate assembly according to any of the claims 15–24, wherein the grates are mounted on a frame by leaf springs.
26. A combustion grate assembly according to any of the claims 15–25, wherein the grates comprises grate bars with apertures provided therein in order to supply combustion air to the fuel to be placed on the grates.

27. A combustion grate assembly according to any of the claims 15–26, wherein the grates are water-cooled or oil-cooled panels.

28. A combustion grate assembly, according to any of the claims 15–27, wherein the grates are inclined by an angle of between 2 degrees and 30 degrees in relation to the horizontal plane, preferably between 4 degrees and 10 degrees in relation to the horizontal plane.

29. A combustion plant comprising a combustion chamber having a fuel inlet and a bottom ash discharge chute, wherein the combustion chamber further comprises a grate assembly according to any of the preceding claims, which is positioned within the combustion chamber between the fuel inlet zone and the bottom ash discharge chute, so that fuel fed through the fuel inlet is deposited on the fuel inlet zone on the first grate and bottom ash discharged from the discharge zone on the last grate is deposited in the bottom ash discharge chute.

30. A method of combusting biomass and/or other fuel, the method comprising the steps of:

- depositing fuel on a fuel inlet zone on a first grate of a grate assembly, said grate assembly comprising a cascade of inclined or horizontal grates, the grates being mounted with a step between the grates such that the fuel moves from one grate in the cascade down to the next grate in the cascade under the influence of the force of gravity,
- igniting the fuel,
- advancing the fuel from the fuel inlet zone on the first grate in the cascade to a bottom ash discharge zone on the last grate in the cascade by vibrating the grates, and
- discharging bottom ash into a bottom ash discharge chute.

31. The method according to claim 30, further comprising the step of vibrating the grates independently of each other.

32. The method according to claim 30 or 31, further comprising the step of vibrating the grates intermittently, i.e. in sequences of vibrations followed by pauses.

33. The method according to claim 32, wherein the time span between the pauses are 18–240 times the time span at which the grates are vibrated.

34. The method according to any of the claims 30–33, wherein at least some of the grates are vibrated at a frequency of 6 Hz–9 Hz

35. The method according to any of the claims 30–34, further comprising the step of vibrating the last grate at a lower frequency than the first grate.

36. The method according to any of the claims 30–35, wherein the pauses between the vibrations of the last grate are longer than the pauses between the vibrations of the first grate.

37. The method according to any of the claims 30–36, wherein the amplitude of vibration of the grates is less than 15 mm.

38. A method combusting biomass or other fuel, the method comprising the steps of:

- depositing fuel on a fuel inlet zone on a first grate of a grate assembly, said grate assembly comprising a cascade of inclined or horizontal grates, the grates being mounted such that fuel is able to move from one grate in the cascade to the next grate in the cascade, each grate being connected to an individual vibrating system for vibrating the grates,
- igniting the fuel,
- advancing the fuel from a fuel inlet zone on the first grate to a bottom ash discharge zone on the last grate by vibrating the grates independently of each other, and
- discharging bottom ash into a bottom ash discharge chute.

39. The method according to claim 38, further comprising the step of vibrating the grates intermittently, i.e. in sequences of vibrations followed by pauses.

40. The method according to claim 39, wherein the time span between the pauses are 18–240 times the time span at which the grates are vibrated.

41. The method according to claim 38, 39 or 40, wherein at least some of the grates are vibrated at a frequency of 6 Hz–9 Hz.

42. The method according to any of the claims 38–41, further comprising the step of vibrating the last grate at a lower frequency than the first grate.

43. The method according to any of the claims 38–42, wherein the pauses between the vibrations of the last grate are longer than the pauses between the vibrations of the first grate.

44. The method according to any of the claims 38–43, wherein the amplitude of vibration of the grates is less than 15 mm.

45. The method according to any of the claims 38–44, wherein the grates are mounted with a step between the grates such that fuel is able to move from one grate in the cascade to the next grate in the cascade under the influence of the force of gravity.

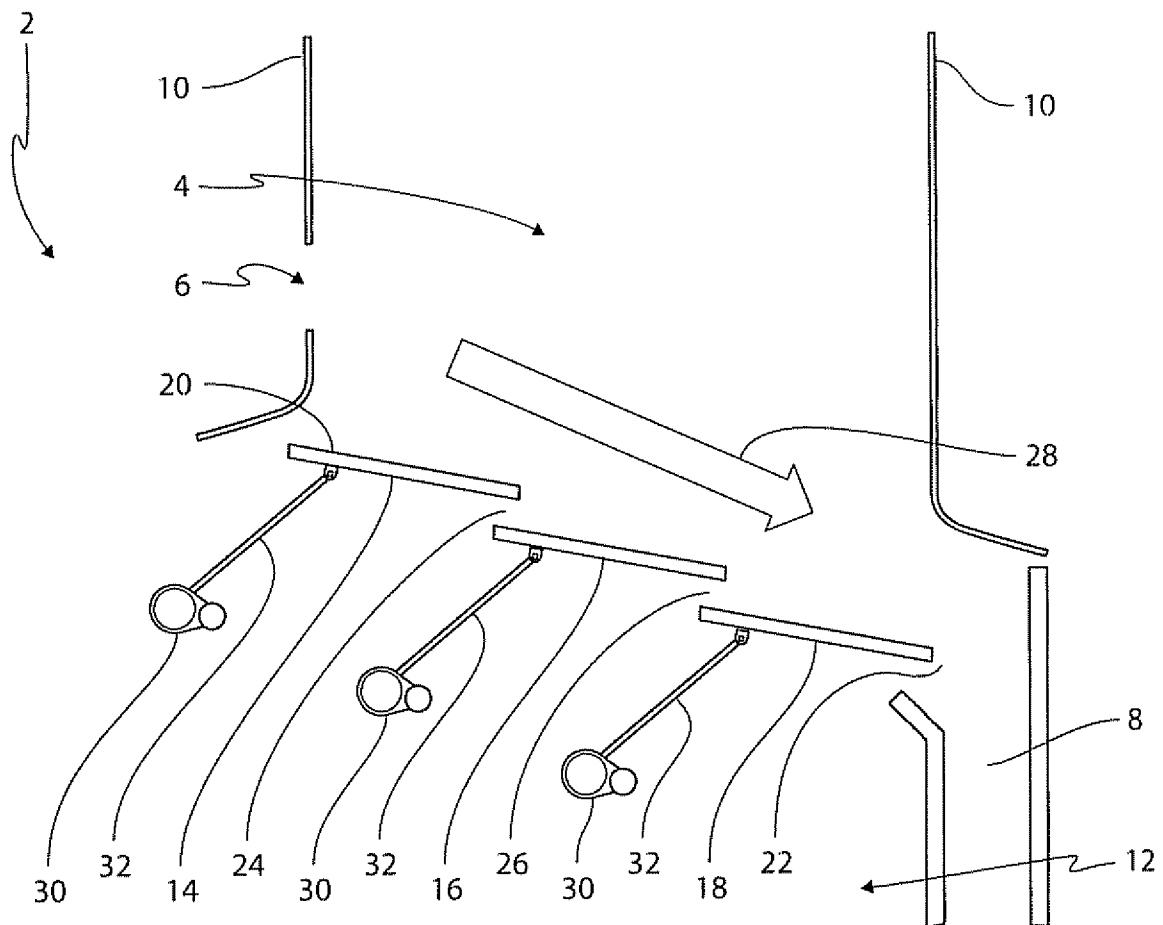


FIG. 1

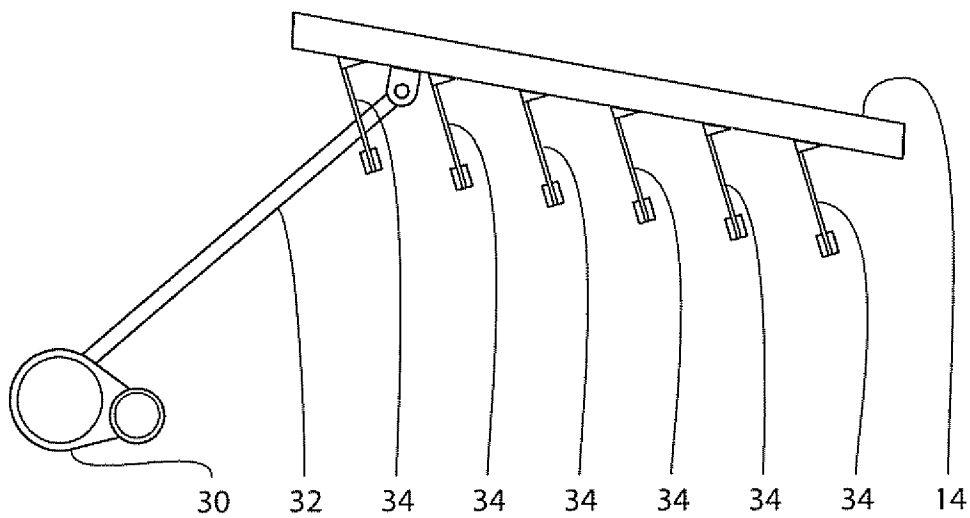


FIG. 2

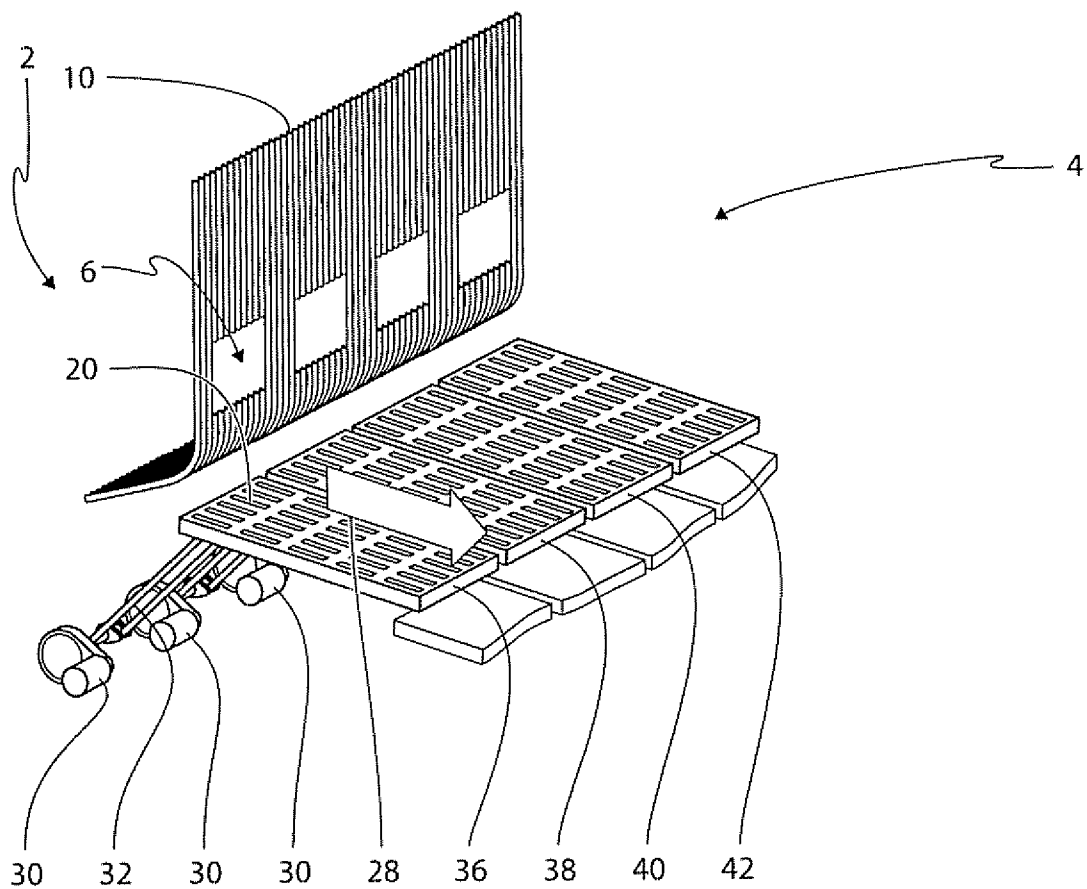


FIG. 3

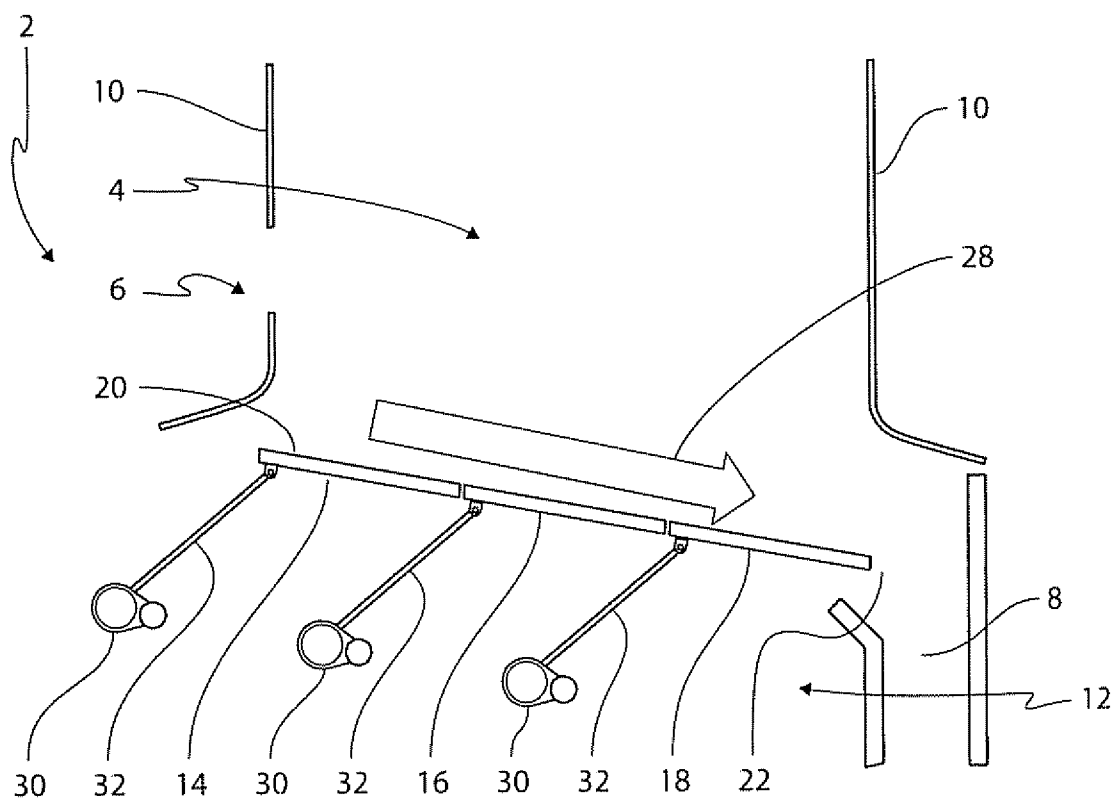


FIG. 4

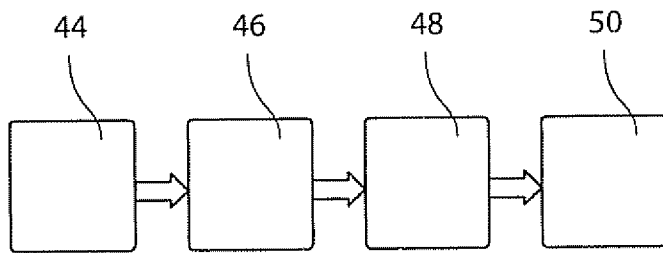


FIG. 5

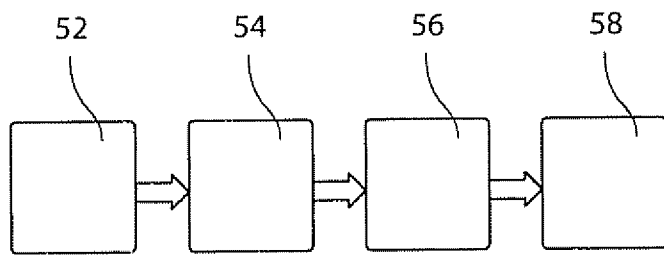


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/053485

A. CLASSIFICATION OF SUBJECT MATTER
INV. F23H3/02 F23H7/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F23H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 655 304 B1 (BARLOW JAMES L [US]) 2 December 2003 (2003-12-02)	1-3,7,8, 11,12, 14-16, 20,21, 23,24, 26,27, 29-31, 35,36, 38,42, 43,45
Y	column 5, line 63 - column 6, line 65 column 8, line 15 - line 65 column 9, line 65 - column 10, line 36 figures 1,5,13,14 ----- -/--	4-6,9, 10,13, 17-19, 22,25, 28, 32-34, 37, 39-41,44

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search

7 March 2013

Date of mailing of the international search report

14/03/2013

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Gavriliu, Costin

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2012/053485

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