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Improved mass fuel combustion system

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(62) Divisional of:

776445

(71) Applicant(s)

Barlow Projects, Inc.

(72) Inventor(s)

Barlow, James L.

(74) Agent/Attorney

Freehills Patent & Trade Mark Attorneys, Level 43 101 Collins Street, Melbourne, VIC, 3000

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ABSTRACT

An improved mass fuel combustion system can be designed in a variety of embodiments and alternatives, including designs which include independent gas feeds, independent gas pulsing, independently controllable vibration systems and an overall control system which can coordinate a host of parameters for optimal combustion. One design includes overlapping grate elements (50) through which combustion gas is introduced and may include apertures to introduce a pulsed mix gas as well as a separate temperature control gas. Efficient poppet design (44) can be used to provide an economical and efficient combustion system.

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COMPLETE SPECIFICATION
STANDARD PATENT

Invention Title: **Improved mass fuel combustion system**

The following statement is a full description of this invention, including the best method of performing it known to us:

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Improved Mass Fuel Combustion System

TECHNICAL FIELD

This invention is primarily directed to an improved stationary combustion apparatus designed to utilize solid fuel such as household and industrial waste, it will be understood that any of various types of combustible, particulate materials may serve as the supply fuel feed for the instant apparatus. The term "mass fuel" referred to herein, is intended to mean any matter being combusted while resting on a surface or traveling on or along a surface. This might be distinguished from methods in which the matter is purposefully suspended in air a substantial distance above a surface. It might also be distinguished from methods, which require the matter to be fragmented before combustion. Mass fuel applications which this invention may be utilized include, but are not limited to elastomeric products, coal, waste coal, sewage sludge, biomass products, municipal solid waste, industrial waste, infectious waste, and manure. Generally, this invention relates to combustion systems which may be utilized as an apparatus and method for the combustion of mass fuel. Specifically, the invention is intended to provide an improved technique for efficiently combusting a mass fuel, possibly having widely varying combustion characteristics, upon a grate assembly in an incinerator or furnace. The combustion system is designed specifically to be an improvement over current incinerator or combustion grate assemblies and current methods of combusting a mass fuel.

BACKGROUND

The difficulty of burning certain mass fuels such as refuse is well known. Refuse often includes a high percentage of slow-burning or wet materials, which can impede combustion and exhibit an erratic burn rate. Furthermore, such compositions can vary continuously with the weather, season, area where collected, conditions under which stored and other uncontrollable and unpredictable variables.

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One known method of burning or combusting refuse incorporates the use of a combustion grate for supporting the fuel during combustion. The method can be directed at dividing the combustion grate into two or three separate treatment zones and, through plenum or supply chambers, may provide combustion air under differing parameters to each one, varying the characteristics of the air to suit the combustion needs. Thus, the air in the first zone containing fresh, un-burned refuse may be heated to dry out the trapped moisture, with combustion possibly not commencing until the refuse has entered the next zone, which may be supplied with a different air mix. The control of combustion in various zones has sometimes been thought to be limited to varying the characteristics of the air flowing to each zone. However, as the thickness of the refuse layer and its combustion characteristics may not be uniform across any one zone, burning time may be longer, possibly dictated by the slowest burning area on the grate.

It can, therefore, be desirable to divide the grate surface into additional zones and to provide independent control of the combustion in each zone to maximize combustion efficiency. Furthermore, the control could optimally be as automatic as possible, so that each zone can be monitored and adjusted continuously, in an effort to maximize the efficiency of the burning to obtain the greatest throughput of fuel. In regard to combustion efficiency, the throughput of fuel may include the disposal through combustion of an input feed material, and or in the alternative, the production of a source of energy, such as heated air, water or steam from the burning operation.

Optimal burn or combustion efficiency may be achieved by simultaneously mixing or agitating the mass fuels and burning or combustion. Although the simultaneous steps of agitating and combusting of mass fuels may have been previously performed in prior combustion techniques, the overall objective of agitating and combusting may be performed in a variety of systems to further optimize combustion efficiency. In particular, it can be desirable to provide a means for mixing or agitating the fuel in specific ways during the combustion process. The result can be such that the overall combustion efficiency is improved.

One system often available for performing mass fuel agitation prior to the present invention appears to provide a stepped combustion grate, whereby a part or all of the steps move in a fashion which apparently aids in the overall mixing and travel of the fuel in a predominant direction. However, it may be desirable to provide a combustion system that incorporates less mechanical complexity than a moving grate system to possibly enhance the economics of the system as well as the throughput or combustion efficiency.

A system to accomplish the mixing or agitation of mass fuel may provide combustion air being fed through the grate assembly as the source of agitation. However, the use of combustion air for the dual purpose of combustion and agitation presents additional problems of system optimization. The use of one controlled air source for combustion as well as fuel agitation may not allow for the optimization of either the combustion or the agitation. In particular, the system may maintain the required combustion air flow to support the overall combustion process. However, the specific requirements needed for the agitation may be neglected. Similarly, the system may maintain the requirements needed to perform the agitation of the fuel. However, the necessary requirements for the proper oxygen-to-fuel ratio for combustion may be neglected either with too much or too little air. Combined with the possible need to adjust to varying fuel combustion characteristics in many instances, the ability to efficiently perform both the task of combustion air supply and fuel agitation with one air source is hampered. Therefore, it is desirable to accomplish both efficient combustion air supply and fuel agitation in a mass fuel combustion system to provide improvement in the overall system efficiency.

One system in particular, previously developed and patented as U.S. Patents 4,955,296 and 5,044,288 by the inventor of the present invention, and hereby incorporated

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by reference, discloses an apparatus and method for the combustion of mass fuel incorporating a stationary grate plate assembly in the combustion system. The system may include an inclined assembly with perforated support tubes for the introduction of agitation air at particular locations along the stepped grate assembly. Combustion and agitation may occur at separate treatment zones along the grate surface in a controlled manner. Although excellent in its addressing of the problems intended, even the above referenced designs can be improved upon. They may not have provided as efficient an introduction source for combustion air and agitation air to the grate assembly as is now possible. System throughput or efficiency may be further enhanced in a system for introducing the combustion air and agitation air by optimized introduction defined by the particular grate plates.

Furthermore, the above referenced patents may also not have optimally provided for the efficient control of combustion parameters apart from combustion air and mix air control. Other system parameters may be monitored and controlled to further enhance the combustion efficiency. It would be desirable, then, to monitor and control the combustion system based upon system parameters, such as, by way of example and not of limitation, combustion chamber temperature, oxygen content of chamber air, carbon monoxide content of chamber air, and mass fuel feed rate, among others. Furthermore, the use of combusted air from the process may be used to further enhance system parameters such as, again by way of example and not of limitation, recycled air for combustion chamber temperature control. System parameters may further be optimized by a particular coordination of air introduction within the combustion system. It is desirable, therefore, to provide a combustion system that can monitor and control combustion parameters of the system and can optimize the parameters through the efficient use and introduction of multiple air sources.

Additionally, agglomerated combustion by-product or perhaps even slag may form within combustion systems resulting from the spent or combusted mass fuel accumulating within the system. A need, therefore, may exist to efficiently remove agglomerated combustion by-product within the system to optimize the throughput of as yet un-combusted fuel or otherwise.

DISCLOSURE OF THE INVENTION

The present invention provides a combustion system that addresses the inadequacies that may have existed with prior incineration or combustion systems. Accordingly, the present invention provides a mass fuel combustion furnace and methods for combusting a mass fuel.

In one aspect of the invention there is provided a mass fuel combustion furnace.

In one embodiment of this aspect there is provided a mass fuel combustion furnace comprising:

a. a mass fuel feed element;

b. a combustion chamber positioned to receive mass fuel from said mass fuel feed element;

c. a plurality of overlapping grate elements within said combustion chamber and establishing an input end, an output end and a length between said input end and said output end across which mass fuel is transported;

d. a combustion gas feed within said combustion chamber;

e. a plurality of overlapping segments of said plurality of overlapping grate elements forming a space between each pair of overlapping segments, wherein said combustion gas feed is positioned for introducing combustion gas through said plurality of spaces;

f. a secondary gas feed within said combustion chamber;

g. a plurality of apertures within said plurality of overlapping grate elements for introducing a secondary gas from said secondary gas feed to said mass fuel transported across said length of overlapping grate elements; and

h. an ash discharge system situated in the vicinity of said output end of said plurality of overlapping fixed grate elements.

In another embodiment of this aspect there is provided a mass fuel combustion furnace comprising:

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a. a mass fuel feed element;

b. a combustion chamber positioned to receive mass fuel from said mass fuel feed element;

c. a grate system within said combustion chamber and having an input end and an output end across which said mass fuel is transported;

d. a combustion gas feed positioned within said combustion chamber and below said grate system;

e. a temperature control gas feed within said combustion chamber;

f. an ash discharge system situated in the vicinity of said output end of said grate system.

In another aspect of the invention there is provided a method of combusting a fuel.

In one embodiment of this aspect there is provided a method of combusting a mass fuel comprising the steps of:

a. providing a combustion chamber positioned to receive a mass fuel;

b. overlapping a plurality of grate elements to establish a grate system within a combustion chamber;

c. establishing a plurality of spaces on said grate system as a result of said step of overlapping said plurality of overlapping grate elements;

d. providing a plurality of apertures on said plurality of overlapping grate elements;

e. feeding a mass fuel into said combustion chamber;

f. introducing a combustion gas through said plurality of spaces on said grate system;

g. introducing a secondary gas through said plurality of apertures on said plurality of overlapping grate elements within said combustion chamber;

h. transporting said mass fuel across said grate system;

i. combusting at least a portion of said mass fuel to produce a combustion product; and

j. discharging said combustion product.

In another embodiment of this aspect there is provided a method of combusting a mass fuel comprising the steps of:

a. providing a combustion chamber positioned to receive a mass fuel;

b. establishing a grate system within a combustion chamber;

c. feeding a mass fuel onto said grate system within said combustion chamber;

d. transporting said mass fuel across said grate system;

e. introducing a combustion gas into said combustion chamber and from below said grate system;

f. combusting at least a portion of said mass fuel to produce a combustion product;

g. introducing a temperature control gas within said combustion chamber;

h. controlling a temperature within said combustion chamber through said temperature control gas; and

i. discharging said combustion product.

Therefore, in one aspect the present invention seeks to provide an improved combustion system for combusting a mass fuel. In particular, there is provided a combustion system for combusting a mass fuel that improves the speed of response and flexibility in the control of combustion of mass fuels. The present invention therefore seeks to provide a combustion system that injects a secondary agitation gas into the fuel mass which can lift, agitate, dry and control the migration of the fuel during the combustion process.

In one embodiment the present invention further seeks to provide a combustion system for combusting a mass fuel without the need for or degree of mechanical movement typically associated with the grate assembly. The present invention therefore seeks to provide a combustion system that allows the grate to be "stationary" to a large degree.

In one embodiment the present invention further seeks to provide a combustion system for combusting a mass fuel without adversely affecting the combustion process. The present invention therefore seeks to provide a combustion system that limits the addition of significant excess oxygen, such as atmospheric air in the fuel introduction system.

In one embodiment the present invention further seeks to provide a combustion system for combusting a mass fuel that provides for agitation gas injection with a plurality of injection points and to independently control the rate of delivery of the gas flow at each point. The present invention therefore seeks to provide a combustion system with control of the velocity or flow of the mix gas at each point where it is released into the fuel and to provide a force available for performing the tasks of mixing, drying and controlling the migration rate of the material.

In one embodiment the present invention further seeks to provide a combustion system for combusting a mass fuel that enhances throughput and combustion efficiency in a system for introducing the combustion gas an agitation gas. The present invention therefore seeks to provide a combustion system that optimizes agitation gas introduction defined by the particular grate plates.

In one embodiment the present invention further seeks to provide a combustion system that minimizes variations in heat release during the combustion process. The present invention therefore seeks to provide a combustion system that controls the fuel feed rate to the combustion process.

In one embodiment the present invention further seeks to provide a combustion system for combusting a mass fuel that minimizes the effects of agglomerated combustion by-product during the combustion process that may discharge through the combustion grate. The present invention therefore seeks to provide a combustion system that efficiently provides for the removal of ash and agglomerated combustion by-product.

In one embodiment of the present invention there is provided a combustion system for combusting a mass fuel that efficiently controls the overall combustion process using multiple parameters. The present invention therefore seeks to provide a combustion system that monitors and optimizes parameters within the system.

In one embodiment the present invention further seeks to provide a combustion system for combusting a mass fuel that provides a plurality of treatment zones for efficient combustion control and subsequent agglomerated combustion by-product removal. The present invention therefore seeks to provide a combustion system with multiple treatment zones, each zone having a separate introduction of combustion and agitation gases, independent rate control of delivery of combustion and agitation gas and separate agglomerated combustion by-product reduction method.

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In one embodiment the present invention further seeks to provide a combustion system for combusting a mass fuel that provides control of the temperatures on the combustion grate surface and throughout the combustion process. The present invention therefore seeks to provide a combustion system using exhaust gas, agitation gas and other types of control.

Other embodiments and aspects of the invention are disclosed throughout other areas of the specification and claims. In addition, the embodiments and aspects may apply either in dependent or independent fashion to a variety of other embodiments and aspects in a variety of embodiments.

As used herein, the term "comprise" and variations of the term, such as "comprising", "comprises" and "comprised", are not intended to exclude other additives, components, integers or steps.

Reference to any prior art in the specification is not, and should not be taken as, an acknowledgment, or any form of suggestion, that this prior art forms part of the common general knowledge in Australia or any other jurisdiction or that this prior art could reasonably be expected to be ascertained, understood and regarded as relevant by a person skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a partial cross-sectional and elevation view of one embodiment of the invention showing a combustion system.

Figure 2 is a plan view of one embodiment of a grate assembly.

Figure 3 is a side view of the grate assembly embodiment depicted in Figure 2.

Figure 4 is an end view, featuring one embodiment of the ash roller, of the grate assembly embodiment depicted in Figure 2.

Figures 5 is a cross-sectional view of one embodiment of grate assembly elements, particularly featuring two interconnected grate plates and associated header tubes, as viewed from the perspective of C-C' of the embodiment of Figure 2.

Figure 6 is a cross-sectional view of one embodiment of a poppet assembly, supply plenum and header tube.

Figure 7 is a cross-sectional view of one embodiment of an ash roller, as viewed from the perspective of section A-A' of the embodiment of Figure 2.

Figure 8 is a second cross-sectional view of one embodiment of an ash roller, as viewed from the perspective of section B-B' of the embodiment of Figure 2.

Figure 9 is a plan view of one embodiment of one grate plate and supporting ribs, header connections and agitation gas apertures.

Figure 10 is a cross-sectional view of the embodiment of the grate plate, supporting ribs, header connections and agitation gas apertures as depicted in Figure 9, as viewed from the perspective of section S-S'.

Figure 11 is a cross-sectional view of the embodiment of the grate plate and supporting ribs as depicted in Figure 9, as viewed from the perspective of P-P'.

Figure 12 is a plan view of one embodiment of a grate plate header assembly and associated supply plenums.

Figure 13 is a cross-sectional view of one embodiment of grate assembly elements, particularly featuring a plurality of interconnected grate plates and associated header tubes, as viewed from the perspective of section D-D' of the embodiment of Figure 2..

Figure 14 is a perspective, partially open, grate assembly diagrammatic view of one embodiment of the invention.

MODE(S) FOR CARRYING OUT THE INVENTION

As can be easily understood, the basic concepts of the present invention may be embodied in a variety of ways. It involves both methods and devices to accomplish the appropriate method. In this disclosure, the methods are disclosed as part of the results shown to be achieved by the various devices described and as steps that are inherent to utilization. They are simply the natural result of utilizing the devices as intended and described. In addition, while some devices are disclosed, it would be understood that these not only accomplish certain methods, but also can be varied in many ways. Importantly, as to the foregoing, all these facets should be understood to be encompassed by this disclosure.

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Although this invention is primarily directed to an improved stationary combustion system designed to utilize "mass" or solid fuels such as household and industrial waste, it will be understood that any of various types of combustible, particulate materials may serve as the combusting fuel for the instant system. The term "mass fuel" or "solid fuel", referred to herein, is intended to mean any matter being combusted while resting on a surface or traveling on or along a surface. In one embodiment the system might also be distinguished from other systems in which the matter is purposefully suspended in air a substantial distance above a surface. It might also be distinguished from other systems which require the matter to be fragmented before combustion. Mass fuel applications in which this invention may be utilized may include, but are not limited to, elastomeric products, coal, waste coal, sewage sludge, biomass products, municipal solid waste, industrial waste, infectious waste, and manure.

As can be understood from the drawings, the basic concepts of the present invention may be embodied in different ways. Figure 1 shows a partial cross-sectional and elevation view of one embodiment of a combustion system of the present invention. As shown, the combustion system of the present invention may relate to a furnace or incinerator, generally designated (10), which may be employed for the purpose of merely incinerating an input mass fuel for disposal or to generate a source of energy, such as hot air, heated water or steam. In this respect, peripheral housing or walls (12) of the furnace may be configured in any suitable well-known manner according to the intended use of the furnace.

In particular, and with references to Figure 1 and 2, the present invention may be directed to the design and configuration of a grate system or assembly (14) serving, in one embodiment of the present invention, to receive and dispose of mass fuel or other material (16) during a combustion process. "Combustion process" or "combustion system" refers generally to a system, inherently including methods and associated devices, for receiving a fuel and combusting the fuel to produce an energy release and to result in substantially combusted material, typically in the form of ash. As is known, by-products of the combustion process may include, but are not limited to, un-combusted material and agglomerated combustion by-product, or even slag (whether used in its technical or vernacular sense) generated by the combustion of mass fuel. In a preferred embodiment, the combustion process takes place substantially on the surface of the grate assembly (14). Preferably, the suspension of un-combusted and combusting mass fuel is minimized in order to maintain complete and efficient combustion of all the supplied mass fuel from the mass fuel feed such as the vertical hopper assembly (18) and feed element or feed table (20).

The grate system or assembly (14) can provide numerous advantages in the disclosed plurality of embodiments. One important advantage is that numerous types of particulate, solid or semi-solid materials, i.e. mass fuels as described supra, exhibiting a wide range of parameters, particularly combustion characteristics, are readily accommodated by the grate assembly (14) given the attendant features of the disclosed combustion system described in various embodiments below. Therefore, an optimum amount of combustion of the mass fuel fed into the system can occur with minimum ash and agglomerated combustion by-product remaining for disposal after or during combustion.

The furnace (10) may further comprise generally, in a preferred embodiment, an upper combustion chamber (20) and a lower combustion chamber (22) where combustion of the mass fuels may preferably take place. An auxiliary burner (24) may also be provided to aid in the start-up and shut down of the combustion system. Combustion gas, and in a preferred embodiment combustion air, can be provided to at least one combustion gas feed or plenums (26) via combustion gas plenum inlets (28). In alternative embodiments, the combustion gas feeds (26) may alternatively or in combination serve as a siftings hopper for combusted mass fuel or ash and for agglomerated combustion by-product from the combusted mass fuel. Furthermore, the combustion gas feeds may alternatively or in combination serve to receive recycled exhaust or combusted gas via plenum inlets (30) to help control combustion parameters, such as temperature or oxygen content as more particularly described below. Recycled exhaust or combusted gas may additionally be introduced into the combustion system via inlets (42). In preferred embodiments, combustion gas may also be introduced through top or bottom combustion gas feeds. This is shown as the top feed embodiment through upper inlets (32).

According to a preferred embodiment, gas may be introduced via the various plenums (26) and inlets (28) (32) and (42) to provide a post-combustion gas feed to the combustion chambers. The introduction of post-combustion gas may serve a variety of purposes, including, but not limited to, the temperature regulation of the combustion chamber and the reduction of ash and agglomerated combustion by-product from the grate assembly and combustion chambers. Post-combustion gas introduction may be performed via a recycled combusted gas system wherein the post-combustion gas introduced may preferably be combusted gas. Additionally, plenums (26) may serve to introduce gases other than combustion or recycled gases, depending on the particular demands of the combustion process, and may include introducing other gases, including, but not limited to, a second combustion gas, uncombustible gases, and grate-cooling gases, among others.

Secondary or even agitation gas feeds (34) may provide, in preferred embodiments, a secondary or agitation or mixing gas source such as for the agitation or mixing of mass fuel, as more fully described below. The secondary gas feeds may further provide, in preferred embodiments for the transportation of mass fuel from an inlet end of the grate assembly (14) near mass fuel feed elements (18) and (20) to an outlet end of the grate assembly near combusted mass fuel or discharge chute (36) and combusted mass fuel or ash conveyor (38). The secondary gas may serve to impart motion or lift to materials located on the grate assembly (14). Additionally, and in preferred embodiments, the secondary or agitation gas feeds may supply secondary gas to dry the materials located on the grate assembly. In this manner, a mass fuel located upon the grate assembly may be

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mixed or agitated, dried and migrated along the grate assembly. The introduction and control of a secondary or an agitation gas to the grate system may be provided by gas poppets (44), more fully described below.

An ash discharge system (39), preferably comprising an ash roller (40), can be provided at the outlet end of grate assembly (14). Ash discharge system (39) may also comprise a discharge chute (36) and removal conveyor (38). The ash roller may serve to control the depth of material on the grate and may further aid in the removal of the materials from the grate system, including, but not limited to, combusted and un-combusted mass fuel, ash, and agglomerated combustion by-product. Thus the ash roller may additionally or alternatively serve to insure the desired or appropriate level of material, particularly that of mass fuel, in the combustion system. Ash roller (40) may, therefore, be adjustable to provide for the control of material removal from or of mass fuel level upon the grate assembly (14). As depicted in Figure 8, an embodiment of the ash roller can comprise a pivotal plate (41) adjacent the ash roller to aid in the removal of ash and to further control the level of mass fuel upon the grate assembly. The conveyor (38) may be filled with water to prevent the undesired introduction of air into the combustion chamber through the ash discharge chute, among other purposes. Additionally, and according to some embodiments, an access door (42) may be provided for manual access to the lower combustion chamber (22). Ports (46) may further provide visual access to the lower combustion chamber.

The grate system (14) may be provided in additional and preferred embodiments as depicted in Figures 2 through 5 and Figures 9 through 14. In particular, Figure 2 provides a plan view of the grate assembly and ash roller (40). The grate assembly may, in preferred embodiments, be comprised of multiple grate elements or plates (50), each grate plate perhaps in an abutting position relative to adjacent width edges (52) of width-adjacent grate plates and in an overlapping relationship relative to length-adjacent grate plates. In this discussion, it may be helpful to understand that the terms "width" and "length" may define directions relative to the dimensions of the grate assembly (14). In particular, an in the depicted embodiment of Figures 2, 5 and 13, the grate plates overlap adjacent grate plates in the length direction of the assembly or in direction (54). Abutment of grate plates may occur along direction (56). Each grate plate may form a substantially planar surface (58) as depicted in Figure 5 and 13, and therefore, grate system or assembly (14) may have a substantially unobstructed planar surface (60) when the grate plates are connected. The substantially planar features of the grate assembly and plates may improve the combustion and migration of mass fuel by minimizing obstruction to the mass fuel.

In particular, and as depicted in Figures 5 and 13, grate elements or plates (50) interconnect such that an overlap (62) may exist between adjacent plates. The interconnect between plates may also be made via overlapping segments (64) such that, when overlapping segments are connected, an interlock system (66) is provided. Each grate plate may preferably be provided with integral tabs (68) to aid in interlocking or connecting adjacent plates as well as perhaps cooling. The interlock system may serve to maintain or hold the planar surface (60) of the grate assembly and thereby preventing substantial non-planar movement of the grate plates. The grate elements (50) may further comprise, according to a preferred embodiment, integral ribs or supports (70) that may serve to provide structural rigidity to the grate assembly and grate plates and may provide a means of cooling the grate assembly. Overlap spacers or spacer elements (72) may be provided integral to said grate plates to establish a space between the overlapping segments (64) of adjacent grate plates.

A space may, therefore, be created between overlapping segments, therefore allowing a gas flow through the overlapping section of grate plates. The gas introduced between spaces of overlapping grate plates can be primarily combustion gas introduced from the combustion gas feeds or plenums (26), via inlets (28). Other gases may be introduced through the space or gap between grate plates, including but not limited to grate cooling gases preferably introduced as recycled combusted gas through inlet 30. Inlets

(28) and (30) of each plenum may be controlled in an independent manner relative to other combustion gas feeds or plenums, a multiple of plenums being depicted in a preferred embodiment of Figure 1. Preferably, the control of combustion or recycled combusted gases may be automatically controlled via automatic control valves, poppets, dampers or other suitable means that may vary the flow or velocity over time.

In one embodiment, the introduction of combustion gas, mix gas, a secondary gas, two gases, or even recycled combusted gas may be made through the plenums such as plenums (26) in a pulsed fashion, via automatic control valves or poppets associated with individual inlets (28) and (30). Therefore, and given a plurality of combustion gas feed or plenums (26) placed along the grate assembly (14) as depicted in Figure 1, zones or sections of the grate assembly may be independently controlled, for example and not by way of limitation, for combustion or for grate cooling.

According to one embodiment, and as depicted in Figures 6, 9, 10 and 14, each grate plate (50) may include inlets, nozzles, or apertures (74) for introducing a secondary, mix, or agitating gas to the top surface of the grate or to material thereupon. More particularly, and according to a preferred embodiment, a secondary, mix, or agitation gas may be introduced through secondary gas feeds or plenums such as plenums (76). Plenums (76) may be in fluid communication with combustion gas feeds or plenums (26) so as to provide the same type of gas. Alternatively, the secondary gas feeds may provide a distinct gas supply. Furthermore, and according to one embodiment, secondary or agitation gas may be introduced from the secondary gas feeds or plenums (76) to secondary or agitation gas headers (78) via a plurality of introducing elements, or preferably, poppets (44). Gas headers (78) may be attached to an underside of grate plates (50) via bolts and bolt holes (79). Preferably, an individual poppet may be actuated to close a header supply tube (80) or gas housing (93). Each poppet (44) may be controlled in an independent manner relative to other poppets, a multiple of poppets depicted in a preferred embodiment of Figure 1.

As shown in Figure 6, each poppet (44) may also include a gas housing (93) having an open end (94). Operating at the open end (94) of the gas housing (93) may be a controllable cap (95) to permit a gas pulse to occur by moving and opening the end of the gas housing (93). As shown, the operation of the controllable cap (95) may be made externally through some type of connection whether mechanical, electrical, or otherwise. To aid in sealing the poppet (44) it may include a seal (96) on either the controllable cap (95) or the gas housing (93) as can be easily appreciated. The seal (96) may also be made of an appropriate material, such as an elastomer or even Viton™ to withstand the potentially harsh environment at the location of the poppet (44). Preferably, the control of secondary, mix, or even agitation gases may be automatically controlled via the poppets, wherein the secondary or agitation gas flow or velocity from zones or sections of apertures (74) of particular grates (50) preferably may vary as needed for proper combustion.

In addition, the introduction of secondary or agitation gas may be made through the plenums (26) in a pulsed fashion, preferably via automatic control of poppets (44) associated with individual gas headers (78). Pulsed gas may provide for the most efficient agitation and other secondary gas functions, including, but not limited to, transportation, cooling and drying of the grate assembly and materials thereupon. Gas headers (78) insure a consistent and controlled flow of gas to sets of apertures (74). Figures 12 and 14 depict a preferred embodiment wherein one header may be in fluid communication with a single poppet (44). However, it is well within the scope of the present invention to provide multiple gas headers (78), associated with a single or multiple poppets, to provide gas flow to a set or zone or section of apertures (74) of particular grates (50). According to a preferred embodiment, therefore, zones or sections of grates may be supplied with automatically controlled secondary or agitation gas. Therefore, and given a preferred plurality of poppets (44) placed along the grate assembly (14) as depicted in Figure 1, zones or sections of the grate assembly may be independently controlled, for example and not by way of limitation, for combustion or for grate cooling.

According to one embodiment, the pulsed introduction of a secondary gas may be independent of the combustion gas feeds or of any gas introduced from the combustion gas feeds or plenums (26). The introduction of combustion gas, including pulsed introduction, may likewise be independent of the secondary or agitation gas plenums (76) and poppets (44). Therefore, multiple pulsing systems, and multiple control of the pulsing systems, for gas introduction may function within the combustion system of the present invention.

According to another embodiment, the combustion system or furnace may comprise a vibration system (90) as generally depicted in Figure 1. The vibration system (90) may also serve to provide agitation of ash and agglomerated combustion by-product or even slag present on the grate assembly (14) and to further aid in transportation of material along the grate assembly. Additionally, the vibration of mass fuel upon the grate assembly may further provide additional exposure of fuel, through agitation, to combustion.

Vibration system (90) may be comprised of a single or multiple vibration elements (92), such as in the form of typical oscillation or vibration devices. The vibration elements may be directly connected to the grate assembly (14) or may be operationally connected to the grate assembly via vibration interconnect elements. According to one embodiment, the vibration element or elements (92) may be connected to zones or portions of grate elements or plates (50) via a vibration interconnect rod (94), as depicted in Figure 9, running the width of either single or multiple grate plates (50) through ribs (70). Accordingly, multiple sections or zones may be vibrated such as to remove agglomerated combustion by-product and to transport ash and agglomerated combustion by-product along the grate assembly. Each zone or portion of the grate assembly (14) or each zone or portion or each grate plate (50) of a plurality of grate plates or elements may be independently vibrated via vibration elements (92). Alternatively, one vibration element (92) may vibrate either the entire grate assembly (14) or an individual zone or portion of grate assembly (14) or an individual zone or portion or individual grate element (50).

According to one embodiment incorporating multiple vibration elements, the vibration system (90) can provide for the independent control of vibration for each vibration element (92) and also for each zone or portion of the grate assembly or grate plates, or of each individual grate plate. Therefore, individual elements, plates, zones or portions of the grate assembly or plurality of grate plates may be independently vibrationally responsive to vibratory movements of the vibration system.

Furthermore, an object of the present invention can be to provide for optimum combustion control of the combustion system. Therefore, a combustion control system (100) may be provided to monitor and control various operational parameters of the combustion system. Temperature sensors may be provided to monitor temperature(s) in the combustion chamber. The control system (100) may be individually responsive to single or multiple temperature sensors and may adjust operational parameters of the system within particular zones or portions of the combustion chamber relative to the grate assembly. In one embodiment a first temperature sensor or sensors may monitor combustion temperatures while a second temperature sensor or sensors may monitor post-combustion temperatures within the combustion chambers (20) and (22).

An additional embodiment of the combustion control system (100) may coordinate combustion parameters of the combustion system to optimize throughput and combustion efficiency. Each of these parameters may be controlled as is easily understood by those of ordinary skill in the art. Coordination of combustion parameters may provide for the control of various combustion system sub-components, such as, but not limited to those set forth in the claims and: mass fuel feed elements (18) and (20); combustion gas feed via plenums (26) and inlets (28) and (32); secondary or agitation gas feed via feed (34), plenums (76) and poppets (34); and post-combustion or recycled combusted gas feeds via inlets (30) and (42), such as but not limited to serving as a cooling or ash and agglomerated combustion by-product reduction system; and any combinations or permutations of such described systems. Monitored combustion parameters within the combustion chambers may comprise, but are not limited to: oxygen content, combustion gas oxygen content, carbon monoxide content, combustion gas carbon monoxide content, temperature, combustion temperature, post-combustion temperature, the relation between a fuel feed rate and a combustion gas feed rate, fuel migration rate, fuel bed depthand any combinations or permutations of such parameters. Parameters may be automatically controlled through programming or other automation as would be readily understood.

As part of controlling the overall combustion process, in introducing the mass fuel to the system it may be desirable to restrict or limit the amount of air introduced with the fuel itself. Thus, a low air fuel feed may be provided so that the amount of air introduced with the fuel is not the typical amount such as would be introduced when a typical often open air feed apparatus would be operated. This can be accomplished by providing doors or the like which limit open air exposure.

Similarly, a third gas feed situated at any location but likely most effective if positioned after combustion has occurred may be provided. This third gas feed can be used to independently control temperature. It may be configured to use recycled or even combusted gas and may feed such either above or below the grate system (14). This temperature control gas may serve as a cooling gas, of course.

The foregoing discussion and the claims that follow describe only some embodiments of the present invention. Particularly with respect to the claims, it should be understood that a number of changes may be made without departing from the essence of the present invention. In this regard, it is intended that such changes — to the extent that they substantially achieve the same results in substantially the same way — will still fall within the scope of the present invention.

As mentioned earlier, this invention can be embodied in a variety of ways. In addition, each of the various elements of the invention and claims may also be achieved in a variety of manners. This disclosure should be understood to encompass each such variation, be it a variation of an embodiment of any apparatus embodiment, a method or process embodiment, or even merely a variation of any element of these. Particularly, it should be understood that as the disclosure relates to elements of the invention, the words for each element may be expressed by equivalent apparatus terms or method terms — even if only the function or result is the same. Such equivalent, broader, or even more generic terms should be considered to be encompassed in the description of each element or action. Such terms can be substituted where desired to make explicit the implicitly broad coverage to which this invention is entitled. As but one example, it should be understood that all action may be expressed as a means for taking that action or as an element which causes that action. Similarly, each physical element disclosed should be understood to encompass a disclosure of the action which that physical element facilitates. Regarding this last aspect, as an example, the disclosure of a "feed" should be understood to encompass disclosure of the act of "feeding" — whether explicitly discussed or not — and, conversely, were there only disclosure of the act of "feeding", such a disclosure should be understood to encompass disclosure of a "feed" or even a "means for feeding". Such changes and alternative terms are to be understood to be explicitly included in the description.

It is simply not practical to describe in the claims all the possible embodiments to the present invention which may be accomplished generally in keeping with the goals and objects of the present invention and this disclosure and which may include separately or collectively such aspects. All elements set forth or claimed may be combined and claimed in any permutaton or combination. Further, while elements may be added to explicitly include such details, the existing claims should be construed to encompass such aspects. To the extent the methods claimed in the present invention are not further discussed, they are natural outgrowths of the system or apparatus claims. Furthermore, the steps are organized in a more logical fashion; however, other sequences can and do occur.

Therefore, the method claims should not be construed to include only the order of the sequence and steps presented.

Finally, any references mentioned in the application for this patent as well as all references listed in any information disclosure originally filed with the application or the priority filing are hereby incorporated by reference. However, to the extent statements might be considered inconsistent with the patenting of this/these invention(s), such statements are expressly not to be considered as made by the applicants. In addition, unless the context requires otherwise, the word "comprise" or variations such as "comprising" or "comprises", should be understood to imply the inclusion of a stated element or step or group of elements or steps but not the exclusion of any other element or step or group of elements or steps.

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The claims defining the invention are as follows:

1. A mass fuel combustion furnace comprising:
    a. a mass fuel feed element;
    b. a combustion chamber positioned to receive mass fuel from said mass fuel feed element;
    c. a plurality of overlapping grate elements within said combustion chamber and establishing an input end, an output end and a length between said input end and said output end across which mass fuel is transported;
    d. a combustion gas feed within said combustion chamber;
    e. a plurality of overlapping segments of said plurality of overlapping grate elements forming a space between each pair of overlapping segments, wherein said combustion gas feed is positioned for introducing combustion gas through said plurality of spaces;
    f. a secondary gas feed within said combustion chamber;
    g. a plurality of apertures within said plurality of overlapping grate elements for introducing a secondary gas from said secondary gas feed to said mass fuel transported across said length of overlapping grate elements; and
    h. an ash discharge system situated in the vicinity of said output end of said plurality of overlapping fixed grate elements.

2. A mass fuel combustion furnace as described in claim 1 wherein said combustion gas comprises combustion air.

3. A mass fuel combustion furnace as described in claim 2 and further comprising a combustion air plenum situated below said plurality of overlapping grate elements and which contains said combustion air.

4. A mass fuel combustion furnace as described in any one of the preceding claims wherein said plurality of overlapping grate elements forms a substantially unobstructed planar surface.

5. A mass fuel combustion furnace as described in claim 4 wherein each of said plurality of overlapping grate elements comprises a substantially planar overlapping grate element.

6. A mass fuel combustion furnace as described in claim 4 wherein said plurality of overlapping grate elements further comprises an interlock system between at least two of said plurality of overlapping grate elements.

7 A mass fuel combustion furnace as described in any one of the preceding claims and further comprising a recycled combusted gas feed within said combustion chamber.

8. A mass fuel combustion furnace as described in claim 7 wherein said recycled combusted gas feed comprises a post-combustion gas feed within said combustion chamber.

9. A mass fuel combustion furnace as described in any one of the preceding claims and further comprising an overlap spacer which establishes said space between each pair of overlapping segments.

10. A mass fuel combustion furnace as described in any one of the preceding claims further comprising a post-combustion gas feed within said combustion chamber.

11. A mass fuel combustion furnace as described in any one of the preceding claims and further comprising a secondary gas plenum adjacent at least one of said overlapping grate elements and which is responsive to said secondary gas feed.

12. A mass fuel combustion furnace as described in any one of the preceding claims and further comprising a vibration element to which at least some of said plurality of overlapping grate elements are responsive.

13. A mass fuel combustion furnace as described in claim 12 wherein said plurality of grate elements comprises a plurality of vibrational grate zones which are each individually responsive to said vibration element and which are independently controllable.

14. A mass fuel combustion furnace as described in any one of the preceding claims and further comprising a combustion control system.

15. A mass fuel combustion furnace as described in claim 14 and further comprising at least one temperature sensor responsive to conditions within said combustion chamber and to which said combustion control system is responsive.

16. A mass fuel combustion furnace as described in claim 15 wherein said at least one temperature sensor responsive to conditions within said combustion chamber and to which said combustion control system is responsive comprises:
   a. a first temperature sensor responsive to conditions within said combustion chamber and to which said combustion control system is responsive; and
   b. a second temperature sensor responsive to conditions within said combustion chamber and to which said combustion control system is also responsive.

17. A mass fuel combustion furnace as described in any one of the preceding claims wherein said mass fuel feed element comprises a low air introduction mass fuel feed system.

18. A mass fuel combustion furnace comprising:
   a. a mass fuel feed element;
   b. a combustion chamber positioned to receive mass fuel from said mass fuel feed element;
   c. a grate system within said combustion chamber and having an input end and an output end across which said mass fuel is transported;
   d. a combustion gas feed positioned within said combustion chamber and below said grate system;
   e. a temperature control gas feed within said combustion chamber;
   f. an ash discharge system situated in the vicinity of said output end of said grate system.

19. A mass fuel combustion furnace as described in claim 18 wherein said temperature control gas feed within said combustion chamber comprises a substantially uncombustible gas feed.

20. A mass fuel combustion furnace as described in claim 19 wherein said substantially uncombustible gas feed comprises a recycled combusted gas feed within said combustion chamber.

21. A mass fuel combustion furnace as described in any one of claims 18 to 20 and further comprising a fuel mix gas feed within said combustion chamber and wherein said temperature control gas feed within said combustion chamber comprises a temperature control gas feed which is independent of both said combustion gas feed and said fuel mix gas feed.

22. A mass fuel combustion furnace as described in any one of claims 18 to 21 wherein said temperature control gas feed within said combustion chamber comprises a cooling gas feed.

23. A mass fuel combustion furnace as described in claim 22 wherein said cooling gas feed comprises a recycled gas feed.

24. A mass fuel combustion furnace as described in one of claims 18 to 23 wherein said temperature control gas feed within said combustion chamber comprises a post-combustion gas feed within said combustion chamber.

25. A mass fuel combustion furnace as described in any one of claims 18 to 24 further comprising an additional temperature control gas feed, wherein said additional temperature control gas feed is positioned within said combustion chamber and above said grate system.

26. A mass fuel combustion furnace as described in any one of claims 18 to 25 wherein said mass fuel feed element comprises a low air introduction mass fuel feed system.

27. A method of combusting a mass fuel comprising the steps of:

a. providing a combustion chamber positioned to receive a mass fuel;

b. overlapping a plurality of grate elements to establish a grate system within a combustion chamber;

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c. establishing a plurality of spaces on said grate system as a result of said step of overlapping said plurality of overlapping grate elements;

d. providing a plurality of apertures on said plurality of overlapping grate elements;

e. feeding a mass fuel into said combustion chamber;

f. introducing a combustion gas through said plurality of spaces on said grate system;

g. introducing a secondary gas through said plurality of apertures on said plurality of overlapping grate elements within said combustion chamber;

h. transporting said mass fuel across said grate system;

i. combusting at least a portion of said mass fuel to produce a combustion product; and

j. discharging said combustion product.

28. A method of combusting a mass fuel as described in claim 27 wherein said step of introducing a combustion gas through said plurality of spaces on said grate system comprises the step of introducing a combustion air through said plurality of spaces on said grate system.

29. A method of combusting a mass fuel as described in claim 28 wherein said step of combusting at least a portion of said mass fuel to produce a combustion product utilizes said combustion air and further comprising the step of recycling said combustion air after said combustion air has been used in said step of combusting at least a portion of said mass fuel to produce a combustion product.

30. A method of combusting a mass fuel as described in claim 29 wherein said step of recycling said combustion air after said combustion air has been used in said step of combusting at least a portion of said mass fuel to produce a combustion product comprises the step of introducing a recycled gas at a location at which said combustion product exists.

31. A method of combusting a mass fuel as described in any one of claims 27 to 29 and further comprising the step of introducing a third gas at a location at which said combustion product exists.

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32. A method of combusting a mass fuel as described in any one of claims 27 to 31 and further comprising the step of vibrating at least a portion of said grate system.

33. A method of combusting a mass fuel as described in claim 32 and further comprising the step of providing a plurality of vibration elements and wherein said step of vibrating comprises the step of independently controlling each of said plurality of vibration elements.

34. A method of combusting a mass fuel as described in any one of claims 27 to 33 further comprising the step of sensing a temperature in said combustion chamber.

35. A method of combusting a mass fuel as described in claim 34 wherein said step of sensing a first temperature in said combustion chamber comprises the step of sensing a combustion temperature in said combustion chamber, and wherein said step of sensing a second temperature in said combustion chamber comprises the step of sensing a post-combustion temperature in said combustion chamber.

36. A method of combusting a mass fuel comprising the steps of:

a. providing a combustion chamber positioned to receive a mass fuel;

b. establishing a grate system within a combustion chamber;

c. feeding a mass fuel onto said grate system within said combustion chamber;

d. transporting said mass fuel across said grate system;

e. introducing a combustion gas into said combustion chamber and from below said grate system;

f. combusting at least a portion of said mass fuel to produce a combustion product;

g. introducing a temperature control gas within said combustion chamber;

h. controlling a temperature within said combustion chamber through said temperature control gas; and

i. discharging said combustion product.

37. A method of combusting a mass fuel as described in claim 36 wherein said step of introducing a temperature control gas into said combustion chamber comprises the step of introducing a substantially uncombustible gas into said combustion chamber.

38. A method of combusting a mass fuel as described in claim 37 wherein said step of introducing a substantially uncombustible gas into said combustion chamber comprises the step of introducing recycled combusted gas within said combustion chamber.

39. A method of combusting a mass fuel as described in any one of claims 26 to 38 and further comprising the step of introducing a mix gas into said combustion chamber and wherein said step of introducing a mix gas into said combustion chamber is independent of both said steps of introducing a combustion gas into said combustion chamber and introducing a temperature control gas into said combustion chamber.

40. A method of combusting a mass fuel as described in any one of claims 36 to 39 wherein said step of introducing a temperature control gas into said combustion chamber comprises the step of introducing a cooling gas into said combustion chamber.

41. A method of combusting a mass fuel as described in claim 40 wherein said step of introducing a cooling gas into said combustion chamber comprises the step of introducing recycled combusted gas into said combustion chamber.

42. A method of combusting a mass fuel as described in any one of claims 36 to 41 further comprising the step of introducing said temperature control gas above said grate system.

43. A method of combusting a mass fuel as described in any one of claims 36 to 42 wherein said step of feeding a mass fuel into said combustion chamber comprises the step of limiting the amount of air introduced into said combustion chamber with said mass fuel.

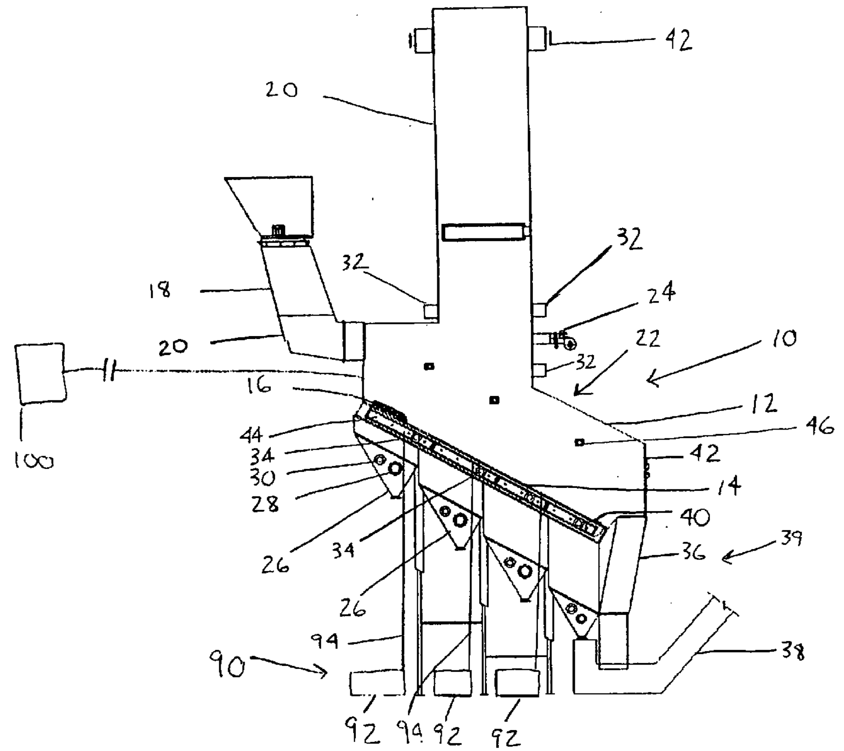

FIGURE 1: COMBUSTION SYSTEM ELEVATION VIEW

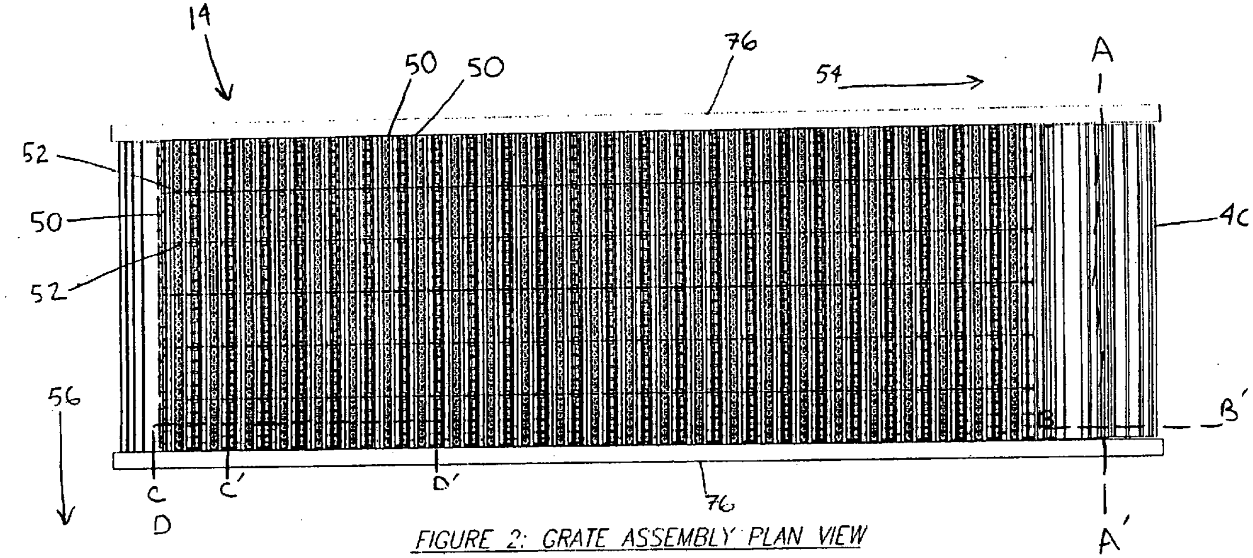

FIGURE 2: GRATE ASSEMBLY PLAN VIEW

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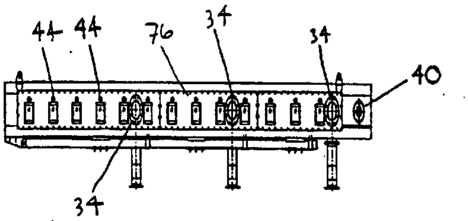

FIGURE 3

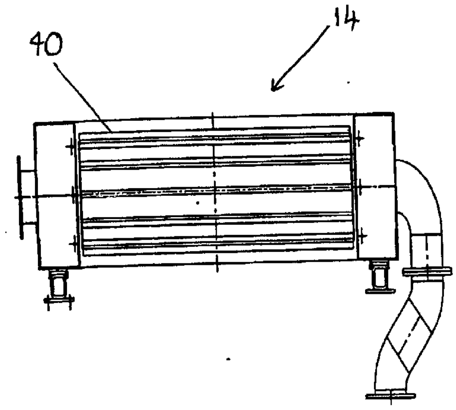

FIGURE 4

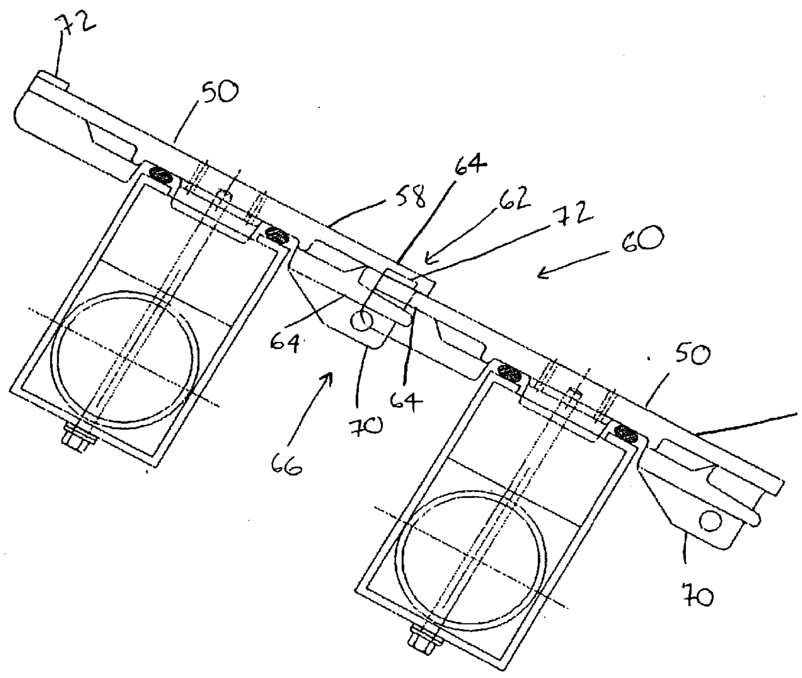

FIGURE 5: TYPICAL GRATE ASSEMBLY CROSS SECTION

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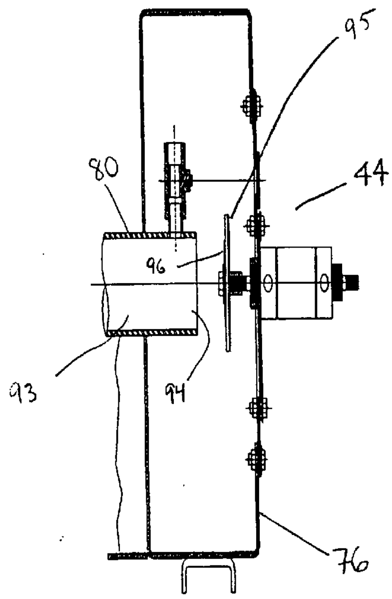

FIGURE 6: POPPET ASSEMBLY SIDE VIEW

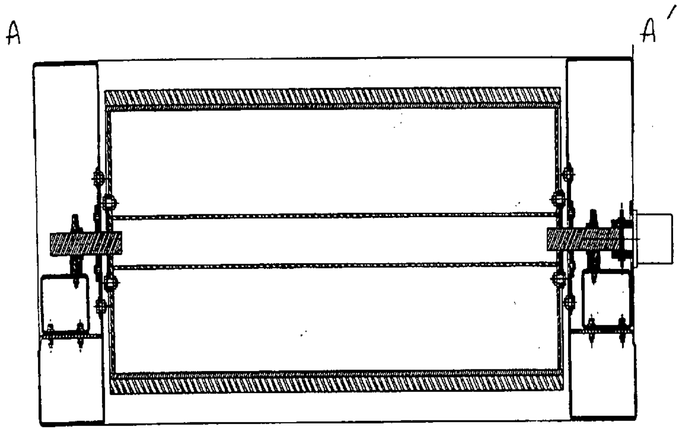

FIGURE 7: ASH ROLLER CROSS SECTION

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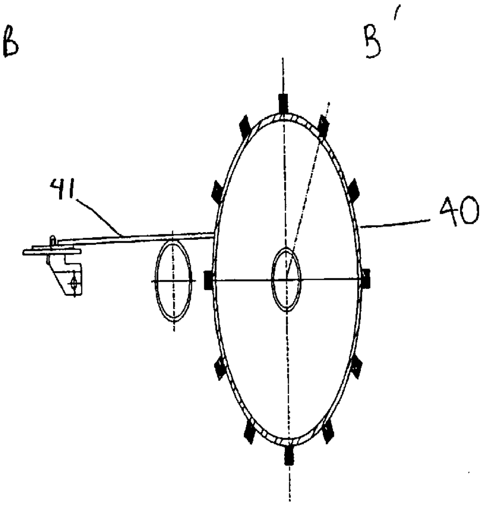

FIGURE 8: ASH ROLLER END VIEW

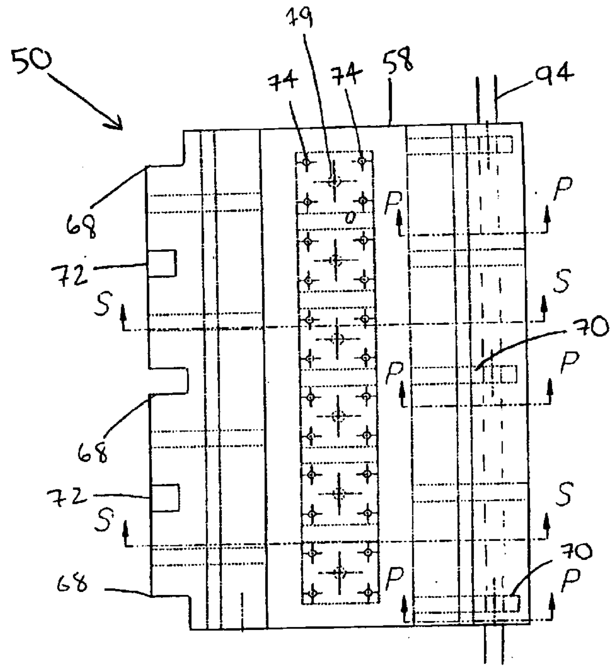

FIGURE 9: GRATE PLATE PLAN VIEW

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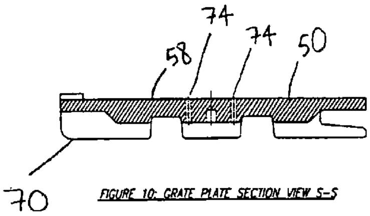

FIGURE 10: GRATE PLATE SECTION VIEW S-S

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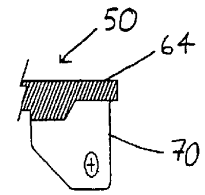

FIGURE 11: GRATE PLATE SECTION VIEW P-P

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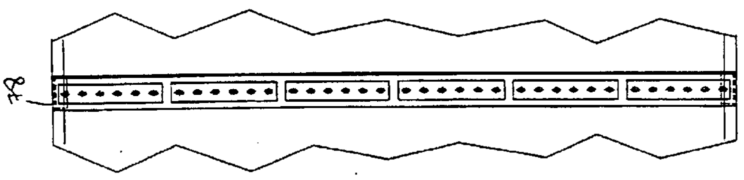

FIGURE 12: GRATE PLATE HEADER ASSEMBLY PLAN VIEW

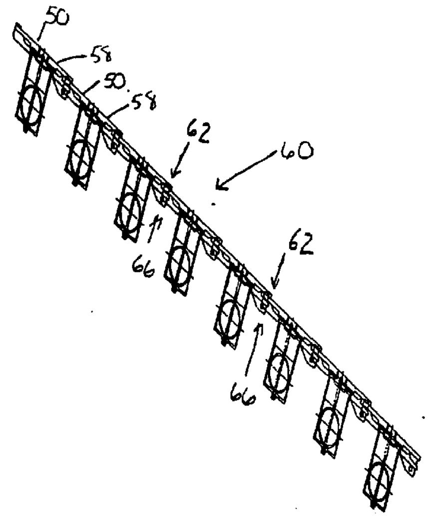

FIGURE 13

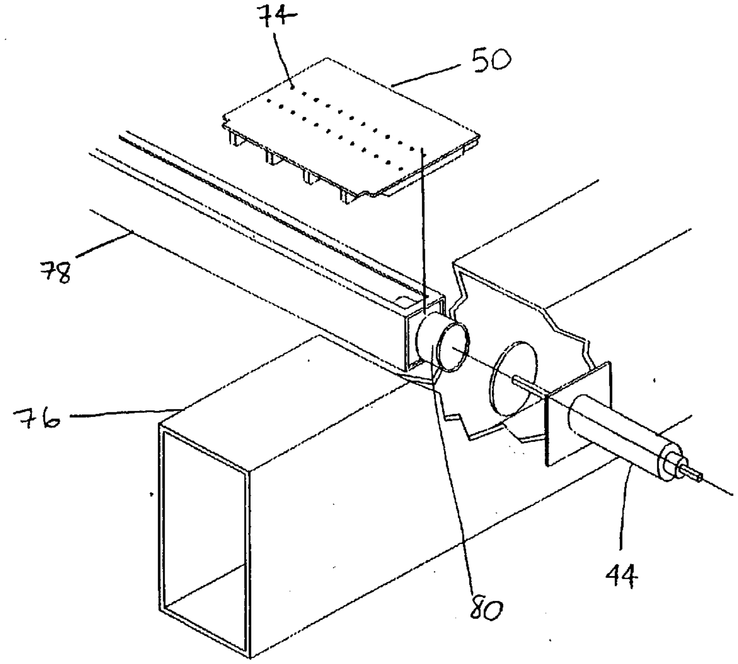

FIGURE 14: GRATE ASSEMBLY DIAGRAM