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Turner et al.

[11] **3,824,937**

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[54] **ENERGY GENERATION SYSTEM ADAPTABLE FOR BURNING DUST-TYPE FUELS**

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[52] **U.S. Cl.** ..... **110/102,** 110/104 R, 222/228, 302/56

[51] **Int. Cl.** **F23k 3/00**

[58] **Field of Search** 110/102, 104; 302/52, 56; 222/228

[56] **References Cited**

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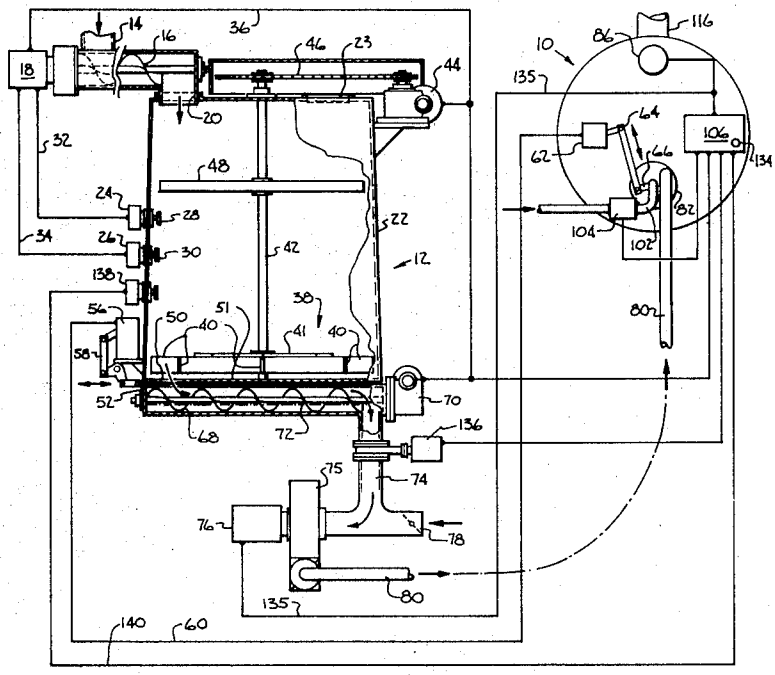
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Primary Examiner—Kenneth W. Sprague
Attorney, Agent, or Firm—Daniel P. Chernoff; Jacob E. Vilhauer, Jr.

[57] **ABSTRACT**

An energy generation system, especially applicable to firetube boilers but also applicable to other combustion-type energy generators, for burning dust-type fuels such as wood sander-dust. The system comprises fuel metering apparatus, responsive to system demands, for accurately controlling the fuel-air ratio and modulating the mass flow rate of the dust-type fuel into the combustion chamber. Dust fuel, normally of variable density, is fed from a large storage hopper into a metering bin sized to hold only a small volumn of the fuel. A rotary agitator within the bin equalizes the density of the dust fuel and divides it into equal volumetric portions which are passed in succession over an opening in the bottom of the bin. The size of the opening is variably modulated by a reciprocating metering gate whose position is determined by a controller responsive to system energy demands. Small predetermined quantities of the fuel, dependent upon the size of the opening, drop through the opening periodically and are transformed into a continuous homogeneous stream of dust fuel by a screw conveyor located below the opening. The conveyor feeds the stream of dust into a blower which transports the dust suspended in an air stream to a dust fuel burner. In the embodiment of the invention adaptable to firetube boilers, the burner comprises a modified boiler diffuser having one or more dust inlet tubes and a continuous supporting pilot to insure continuity of burning. The boiler embodiment also includes a boiler extension section having a trap for retaining any large particles of the fuel within the boiler to insure their complete combustion.

21 Claims, 6 Drawing Figures



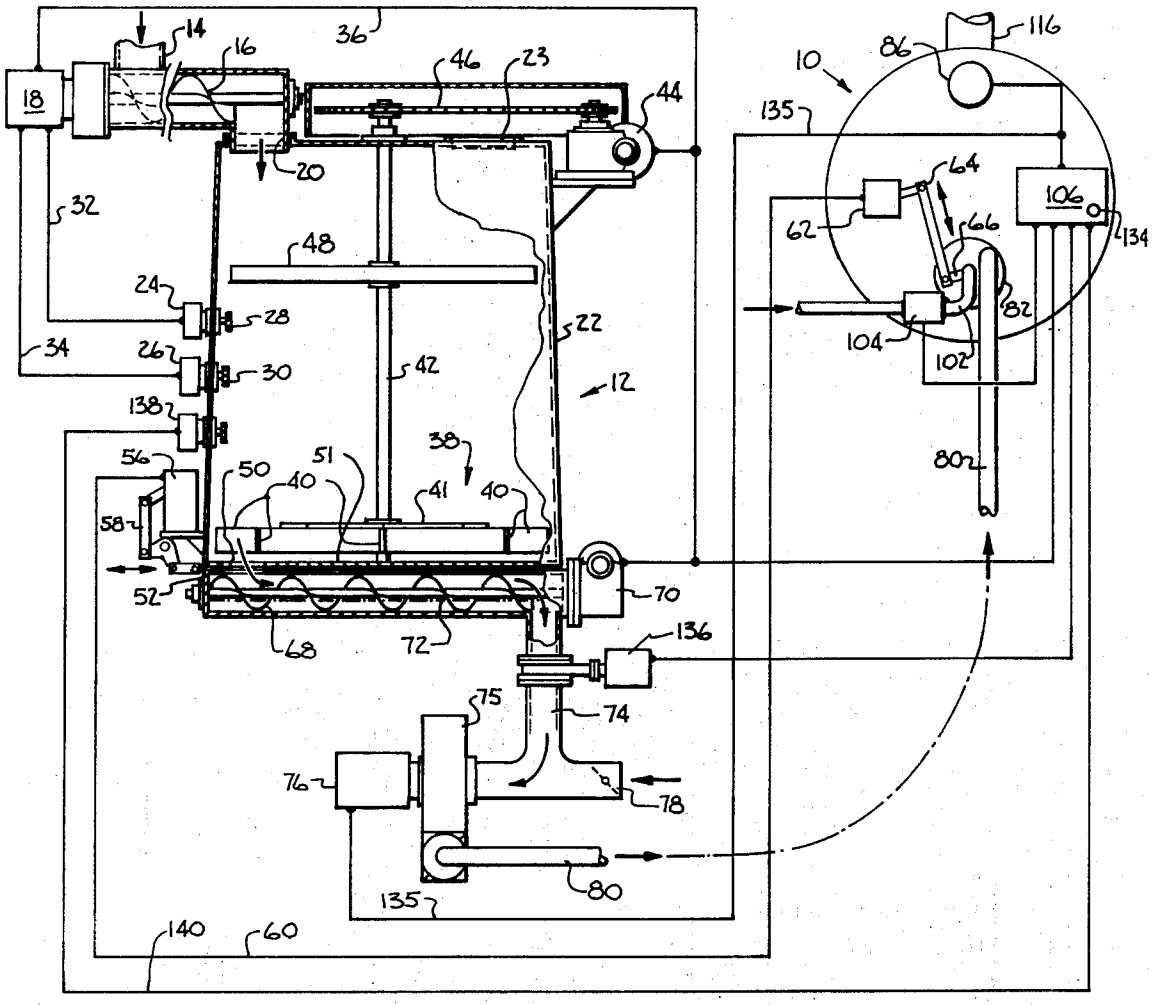


FIG. 1

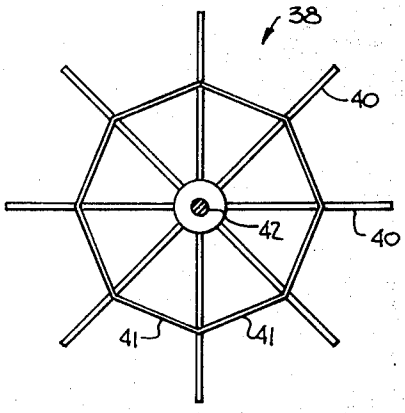


FIG. 2

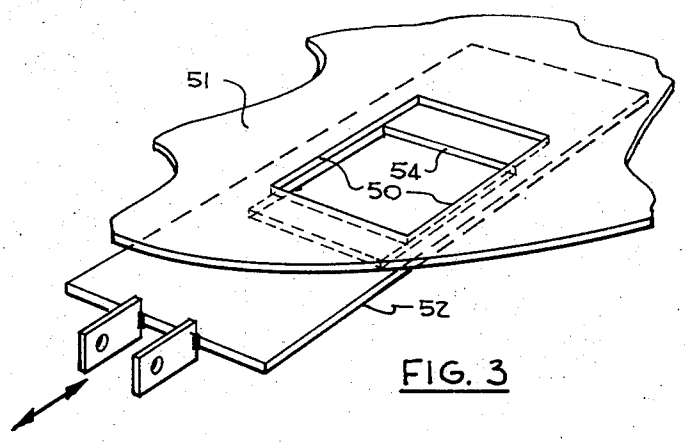


FIG. 3

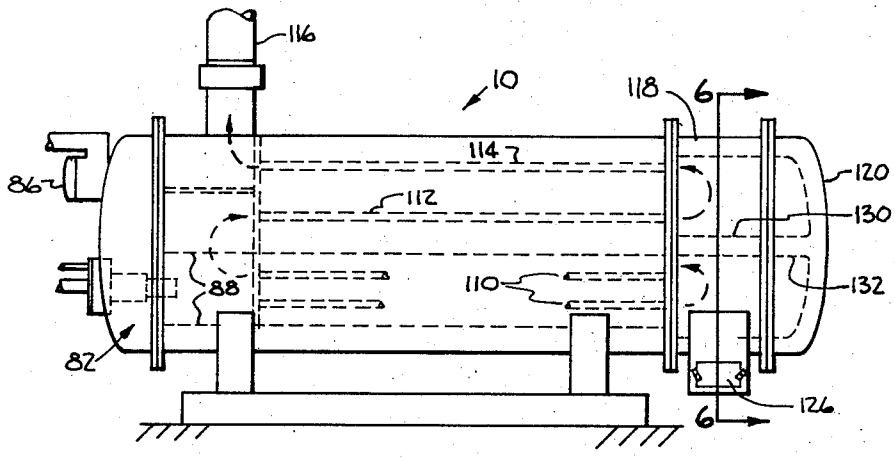


FIG. 5

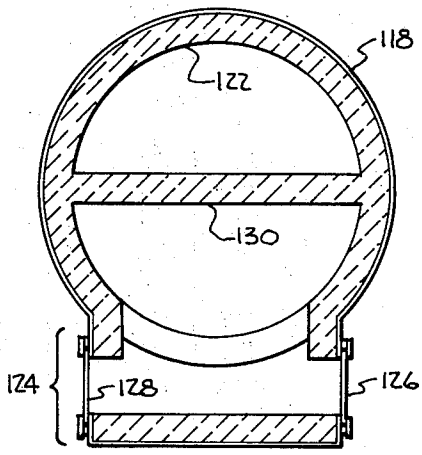


FIG. 6

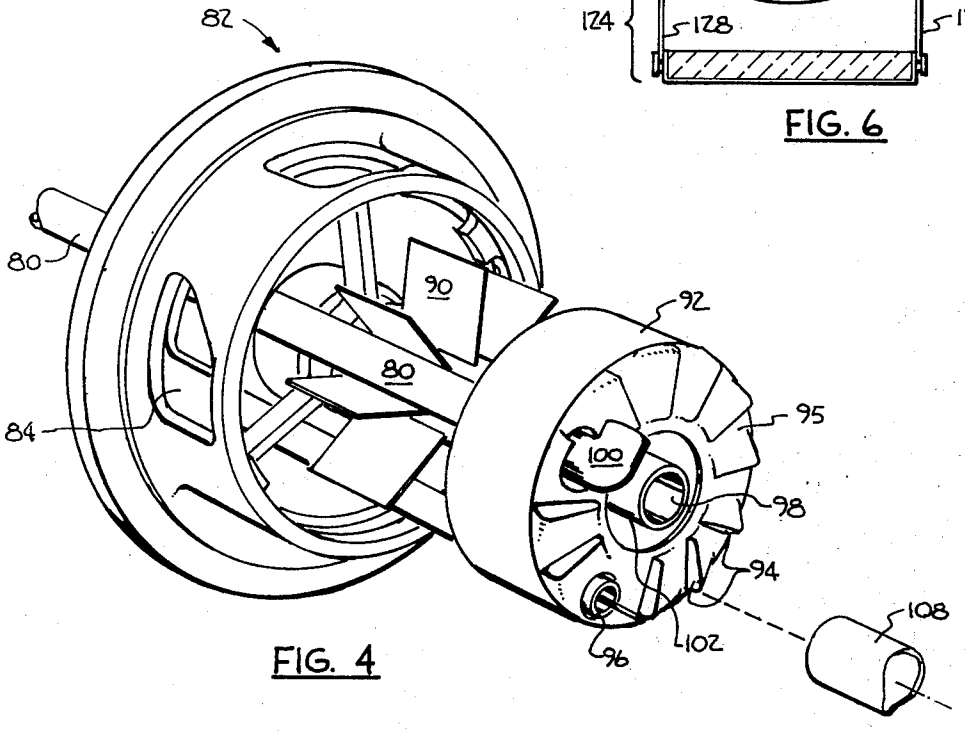


FIG. 4

ENERGY GENERATION SYSTEM ADAPTABLE FOR BURNING DUST-TYPE FUELS

BACKGROUND OF THE INVENTION

This invention relates to a combustion-type energy generation system, especially applicable to firetube boilers but also adaptable for use with other combustion-type energy generators, for utilizing dust-type materials as the primary fuel. More particularly, the system comprises demand-responsive metering apparatus capable of controlling the fuel-air ratio and mass flow rate of the dust fuel with a degree of accuracy comparable to that obtainable with gas and oil fuels.

In the past, wood dust waste produced by lumber sanders (hereinafter referred to as sanderdust) has been utilized as a fuel supplement in watertube boilers and other large heating devices. However considerable difficulty has been encountered in attempting to employ the sanderdust as the major component of the total fuel supply. One of the difficulties referred to is that the burning of sanderdust as a primary fuel tends to cause extremely high temperatures within the combustion chamber, resulting in accelerated deterioration of the combustion chamber walls. In addition, with sanderdust as the major component of the fuel supply, continuous accurate metering of the fuel mass flow rate into the combustion chamber in accordance with the desired air-fuel ratio and energy demands of the system is virtually impossible, thereby causing further problems. For example the mass flow rate of fuel to a boiler must be responsive to boiler pressure, so as to increase the fuel supply in response to lower boiler pressure and decrease the supply in response to higher pressure relative to a predetermined pressure setting. If the fuel mass flow rate is not accurately responsive to boiler pressure, "pulsing" of the boiler due to uncontrolled fluctuations in energy input, and possible explosion, may result. In addition, the lack of adequate control of the fuel-air ratio may cause imcomplete fuel combustion and thus excessive pollutants in the flue gases, resulting in violation of applicable governmental regulations concerning flue gas purity.

As a consequence of these various difficulties it has been necessary, in prior art systems utilizing sanderdust as a fuel component, to employ a more easily metered fuel such as natural gas or oil as the major component of the fuel supply, employing the sanderdust only as a fuel supplement to limit the foregoing detrimental effects of the dust-type fuel. This practice is expensive however, requiring substantial amounts of purchased fuel and high-capacity equipment, such as watertube boilers, to utilize and dispose of sufficient quantities of the sanderdust waste. Consequently most small producers, who do not have sufficient energy requirements to warrant the cost of high-capacity energy generators, continue to be faced with sanderdust waste disposal problems while at the same time having to resort primarily to purchased gas or oil fuels to satisy their energy requirements.

The metering problems connected with the use of sanderdust referred to above, which have prevented its use as a primary fuel, are caused principally by the nonuniform density characterizing such fuel. As evidenced by the systems shown in Bros. U.S. Pat. No. 2,228,751 and Daniels U.S. Pat. No. 2,621,083, attempts have been made to meter the flow of dust-type fuels into a combustion chamber by controlling the speed of a

screw conveyor which transports the fuel. However, since the density of the compacted dust transported by each turn of the conveyor may vary widely, thereby uncontrolably varying the mass flow rate of the injected fuel, such systems do not eliminate the foregoing problems. Accordingly a need presently exists for apparatus, adaptable to boilers and other types of energy generation systems, capable of continuously and accurately controlling the fuel-air ratio and metering the mass flow rate of dust-type fuels in response to system energy demand, so as to permit such systems to utilize dust-type materials as the primary fuel source without causing unacceptable pollution of the flue gases or uncontrolled energy "pulsing." In addition, such system should be of the type capable of limiting combustion chamber temperatures so as to avoid accelerated deterioration of the chamber walls.

SUMMARY OF THE PRESENT INVENTION

The present invention is directed to an energy generation and combustion system capable of utilizing a dust-type fuel, particularly sanderdust, as its primary fuel (consitituting up to 90 percent of the total fuel energy input) while eliminating all of the abovementioned problems normally encountered with dust fuels.

The fuel supply portion of the system includes a metering bin for accepting dust fuel of variable density from a large storage hopper, the metering bin being sized to hold only a small volume of the fuel so as to minimize any tendency of the fuel to become compacted in the bin. Fuel level sensors are provided for selectively starting and stopping a conveyor which transports the fuel from the storage hopper into the metering bin, and a further sensor is provided for interrupting the supply of dust fuel to the burner if the fuel in the metering bin drops below a predetermined level. A rotary agitator, comprising equally spaced radial paddles, loosens and homogenizes the dust fuel in the bin, equalizing its density and dividing it into equal mass portions which are passed in succession over a discharge opening in the bottom of the bin. A reciprocating metering gate, movable by means of a controller responsive to system energy demands, determines the size of the discharge opening and thereby determines the mass of small increments of the fuel which periodically drop through the opening as the agitator rotates. The agitator and discharge opening cooperate to prevent any compaction of the fuel during the metering step to maintain the homogeneity established within the metering bin and thereby maintain a consistent predetermined mass flow rate variable only in response to movement of the metering gate. A screw conveyor located below the opening, having a volumetric capacity substantially greater than that needed to transport the fuel so as to further guard against any densification or agglomeration of the fuel, transforms the increments into a continuous homogeneous stream of loose dust fuel and feeds the stream into a blower-powered pneumatic conveyor which mixes the dust with a supporting air stream and transports it through a dust inlet conduit into the combustion chamber.

In its preferred form, the system utilizes sanderdust as the major fuel component for a firetube boiler which, because of its water-jacketed combustion chamber, is particularly adaptable for rapidly dissipating heat from the combustion chamber and thereby effec-

tively preventing accelerated deterioration of the chamber walls due to the high temperatures characterizing dust burning. The boiler is preferably modified by the provision of an extension section at one end thereof, having a trap for retaining within the boiler any gross particles contained in the fuel so as to insure their complete combustion and prevent their escape with the flue gases. The diffuser section of the boiler is also modified by the inclusion of one or more dust inlet conduits and a gas or oil supporting pilot to insure continuity of burning.

The provision of a metering bin for transforming dust fuel of variable density into a homogeneous mixture of uniform density, coupled with the metering agitator and gate for discharging periodic fuel increments from the bin in quantities of predetermined mass and the screw conveyor for transforming the increments into a continuous homogeneous stream, all without increased densification of the fuel, cooperate to insure that the dust fuel will enter the combustion chamber at a constant predetermined mass flow rate variable only in response to variations in the adjustment of the gate. Thus the fuel-air ratio can be continuously and reliably controlled. In addition, the variable metering gate continously insures that the fuel flow rate is proportional to system energy demands. Accordingly the "pulsing" and pollution problems encountered previously when dust fuels were used as the primary fuel component are eliminated. The provision of a continuous supporting pilot flame enhances the foregoing advantages by insuring smooth and continuous burning of the fuel, while the provision of a trap in the combustion chamber for collecting and retaining unusually large particles in the fuel stream further insures against the presence of unacceptable pollutants in the flue gases.

Accordingly it is a primary objective of the present invention to provide an energy generation system, adaptable for utilizing dust-type fuel as the primary fuel component, having fuel metering apparatus for continuously insuring a predetermined mass flow rate of such fuel into the combustion chamber variable only in response to control parameters such as system demands, thereby eliminating the possibility of uncontrolled energy "pulsing" or unacceptable pollutant content in the flue gases.

It is a further objective of the present invention to adapt a firetube boiler to burn dust-type fuel, especially sanderdust, as a primary fuel so as to take advantage of the special heat dissipation features of such boiler to alleviate the excessive temperature problems normally occasioned by dust fuel burning.

The foregoing and other objectives, features and advantages of the present invention will be more readily understood upon consideration of the following detailed description of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partially schematic assembly view of an energy generation system adapted for burning dust-type fuels depicting an enlarged, partially sectional side view of the fuel metering bin and its associated equipment.

FIG. **2** is a top view of the agitator employed in the metering bin.

FIG. **3** is a perspective detail view of the discharge opening and movable gate adjacent the bottom of the metering bin.

FIG. **4** is a perspective view of a boiler burner and diffuser assembly modified to accommodate dust fuel injection.

FIG. **5** is a side view of a multi-pass firetube boiler modified by the addition of a boiler extension section in accordance with the present invention.

FIG. **6** is a sectional view of the boiler extension section taken along lines **6—6** of FIG. **5.**

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to FIG. **1,** the energy generation system of the present invention comprises an energy generator **10,** preferably a firetube boiler modified in a manner to be described hereafter, and dust fuel feed apparatus designated generally as **12** for supplying metered dust fuel to the combustion chamber of the boiler **10.** The dust fuel preferably constitutes sanderdust waste produced by power sanders of the type which treat plywood, hardboard and other lumber products, such dust being substantially dry (approximately 6–15 percent moisture content by weight) and having an average particle size of approximately 10 microns. A small quantity of gross wood particles, such as shavings or splinters, of a size much larger than the dust particles, is usually found mixed with any given quantity of sanderdust. Such waste presently represents a major disposal problem for the wood products industry but has the potential, if used as a fuel, to decrease substantially the cost of purchased fuels required for energy generation. The dust fuel may be stored in a large storage hopper of any convenient design (not shown), from which it is emptied gradually through a conduit **14** in response to the rotation of a large feed screw conveyor **16** rotatably powered by a motor **18.** The screw conveyor **16** empties the dust fuel through a chute **20** into a metering bin **22** having a volumetric capacity much smaller than that of the fuel storage hopper. The bin **22** is equipped with a pressure relief door **23** adaptable to be easily dislodged in response to any pressure-build-up in the bin **22,** so as to guard against any possibility of explosion within the bin. Protruding through the wall of the bin **22** at different predetermined heights are a pair of level sensors **24, 26** respectively, each preferably of the type having a rotor member **28, 30** inside the bin rotatably driven by an electric motor whenever such rotation is not impeded by surrounding dust fuel and, whenever such rotation is impeded, causing a reverse torque which actuates a level sensing switch. The two level sensors are coupled by electrical circuits **32, 34** to the screw conveyor motor **18** in such a way as to selectively control the input of current to the motor through a power line **36.** Whenever the level of the dust fuel in the bin **22** is high enough to impede the rotation of the rotor **28,** the switching device in the level sensor **24** interrupts power to the motor **18** and stops the conveyor **16** from depositing fuel into the bin **22.** The conveyor remains stopped until the fuel in the bin drops below the level of the rotor **30,** thereby permitting the rotor to turn. This in turn causes a signal to be transmitted by the switching mechanism of level sensor **26** closing the power circuit of motor **18** and restarting the conveyor **16** to deposit additional dust fuel into the bin. The conveyor **16** continues operating until the fuel

level once more reaches the rotor **28,** at which time the switching mechanism of the level sensor **24** interrupts power to the motor **18,** and so forth.

The dust fuel entering the metering bin **22** through chute **20** will normally be of variable density due to its long period of repose in the storage hopper and the mechanical compressive forces exerted on it by the screw conveyor **16.** The purpose of the metering bin **22** is to homogenize the dust fuel and equalize its density so that its mass flow rate into the combustion chamber of the boiler **10** can be regulated accurately. To this end the size of bin **22** and the spacing of the level sensors **24, 26** are such that the amount of fuel added by each start of conveyor **16** is only enough to accommodate the boiler **10** for approximately 20 minutes. This small capacity of the bin **22** causes a relatively rapid turnover of fuel in the bin, thereby insuring that it will not have much chance to settle and become compacted by virtue of its own weight. In addition, the level sensor arrangement insures that the height of the material in the bin, and thus its compressive weight, will be subject to little variation during operation.

Aided by the foregoing features, a rotary agitator **38** is provided within the bin to homogenize and equalize the density of the fuel dust. The agitator comprises eight paddle members **40** (FIG. **2**), secured together by reinforcing bars **41,** equally spaced radially about a vertical drive shaft **42** powered by a motor **44** through a chain and sprocket assembly **46.** The paddles **40** are driven by the shaft **42** at a constant speed of approximately **20** rpm to provide the necessary agitation. Concurrently a plow member **48,** also driven by the shaft **42,** insures that the height of the fuel dust across the bin will be level rather than being permitted to pile up on the side where the fuel enters through the chute **20,** equalizing gravitational pressure on the fuel throughout the bin and promoting uniform fuel density.

The homogeneity of the fuel dust is greatest at the bottom of the bin where the fuel is divided into eight equal segments between adjacent pairs of paddles **40.** As the paddles rotate, an increment of each successive fuel segment falls through a rectangular discharge opening **50** (FIGS. **1** and **3**) formed in the bottom **51** of the bin **22** below the area of rotation of the paddles. Since the paddles rotate at constant speed, and since the density of the successive fuel segments is uniform, the mass of each such fuel increment is predetermined by the size of the discharge opening **50.** As long as the area of the opening remains constant, the mass flow rate of the increments passing through the opening also remains constant. Conversely, any variation in the size of the opening causes a corresponding variation in the mass flow rate of the fuel.

As shown most clearly in FIG. **3,** a reciprocating metering gate **52** having a rectangular opening **54** formed therein is provided for varying the effective size of the discharge opening **50.** The position of the gate **52** is responsive to an electrically operated controller **56** of any suitable type, such as a Honeywell "modutrol" unit, which controls the reciprocation of the gate **52** through a linkage assembly **58.** The controller **56,** in turn, is responsive to signals received throuh line **60** from a standard energy demand sensing device **62,** such as a Honeywell "pressuretrol," which regulates both the amount of fuel and the amount of air admitted to the combustion chamber of the boiler **10.** Fuel regulation is accomplished through controller **56,** whereas air flow is modulated by means of a conventional damper within the boiler controlled by a reciprocating arm **64** acting on a damper lever **66.** In this way the device **62** regulates both the air-fuel ratio and the absolute mass flow rate of both the fuel and the air in response to variations in energy demands of the system. In the boiler embodiment, the energy requirements are sensed as a function of the boiler steam pressure, and accordingly if boiler pressure drops below a predetermined level the demand response device **62** operates to increase both the air and fuel flow rates. Conversely, if boiler pressure increases to a level higher than a predetermined limit, the device **62** reduces both the fuel and air input.

The accuracy of the foregoing control over the fuel-air ratio and absolute fuel flow rate depends on the capability of the fuel metering apparatus to deliver a consistent, predetermined mass flow rate of fuel in response to a particular signal received from the device **62.** If the density of the dust fuel being metered were not uniform, the fuel increments passing through the discharge opening **50** at any particular setting of the metering gate **52** might be volumetrically equal but not necessarily equal with respect to mass, thereby causing uncontrolled fluctuations in fuel-air ratio and in the fuel energy input to the combustion chamber. Such is the problem encountered with prior art screw conveyor metering apparatus, which causes variable compaction of the fuel while transporting it through the screw and thereby causes uncontrolled variations in mass flow rate despite precise control of the screw speed. Accordingly the metering apparatus of the present invention, specifically the metering agitator **38** and discharge opening **50,** cooperate to homogenize the fuel and equalize its density prior to metering and then, during metering, prevent the fuel from being compacted to a density greater than that to which it has been previously homogenized by permitting the fuel simply to fall by gravity in periodic increments through an opening of predetermined size. This insures a consistent mass flow rate of the fuel from the bin, variable only in response to adjustment of the metering gate **52.**

The periodic fuel increments passing through the discharge opening **50,** while having a reliable mass flow rate, are not yet in continuous stream form suitable for introduction into the boiler combustion chamber. Accordingly a screw conveyor **68** driven by a motor **70** is included as part of the metering apparatus to receive the increments from the discharge opening **50** and transform them into a continuous stream. It is important that the screw conveyor **68** have a volumetric capacity substantially in excess of that necessary merely to transport the fuel increments received, so that the conveyor will not cause compaction of the dust fuel which would otherwise tend to destroy the uniformity of the mass flow rate. Accordingly the conveyor **68** is preferably of such a capacity and operates at sufficient speed that the fuel can be carried along therein at a level at or below the longitudinal axis of the conveyor, as indicated by the fuel level line **72** shown in phantom in FIG. **1.** With such high volumetric capacity relative to the fuel flow, the screw conveyor **68** has no opportunity to compact the fuel dust but rather merely transforms it into a continuous, evenly flowing stream.

The fuel stream is fed from the screw conveyor **68** through a conduit **74** into the intake of a pneumatic conveyor blower **75** powdered by a motor **76.** The

blower **75** mixes the fuel with air entering through an inlet **78** and transports the fuel by means of the supporting air stream through a fuel feed inlet conduit **80,** at a linear speed greater than the possible speed of flame propagation back through such conduit, to a modified burner and diffuser assembly **82** mounted within the combustion chamber of the boiler **10.**

As best seen in FIG. **4** the burner and diffuser assembly **82,** as originally provided by the boiler manufacturer, comprises a conventional rotary damper **84** operated by the aforementioned lever **66** for controlling the influx of air from the boiler blower **86** into the combustion chamber. Also included are a set of air-straightening vanes **90** and a diffuser **92** having directional apertures **94** formed in the face **95** thereof for directing the combustion air into a swirling pattern as it is emitted from the face of the diffuser. The assembly **82** also normally includes a natural gas starting pilot **96** and, assuming that the boiler is intended to be operated selectively either on gas or oil fuel, an oil gun is provided in the opening **98** in the center of the diffuser **92** with gas jets surrounding the perimeter of the diffuser (not shown).

In the present invention, where the objective is to burn primarily dust-type fuel rather than primarily gas or oil fuel, certain modifications to the burner and diffuser assembly **82** are required. One of these is the addition of at least one dust fuel inlet conduit **80** protruding through the face of the diffuser **92,** such conduit preferably having a directional end piece **100** facing tangentially to the swirl pattern of the diffuser so as to introduce the dust fuel smoothly and evenly into the combustion air emitted from the face of the diffuser. Depending upon the size of the boiler, one or more such dust inlet conduits **80** spaced around the diffuser may be desirable. In addition, a gas or oil supporting pilot **102** is mounted in the face of the diffuser, such supporting pilot having a fuel control valve **104** responsive to the boiler master control **106** (see FIG. **1**) for supplying fuel to the pilot **102** continuously concurrently with the injection of the dust so as to insure continuous combustion of the dust fuel. The quantity of gas or oil fuel supplied to the supporting pilot **102** preferably constitutes about ten percent of the total fuel energy input to the combustion chamber of the boiler, the remainder of the fuel energy input being derived from the dust fuel. In the embodiment of the modified burner and diffuser assembly **82** shown in FIG. **4,** the supporting pilot **102** is depicted as occupying the opening **98** in the center of the diffuser **92** where the oil gun provided by the boiler manufacturer is normally located. Alternatively, one or more such supporting pilots, depending upon the size of the boiler, may be mounted in the face **95** of the diffuser. A photelectric scanner **108,** provided by the boiler manufacturer for sensing the presence of a combustion flame at the face of the diffuser, operates through the master control **106** to selectively interrupt the introduction of fuel into the combustion chamber in response to any interruption in the combustion flame, in a manner to be described more fully hereafter.

With reference to FIG. **5,** the boiler **10** is preferably of the firetube type, so as to take advantage of its water-jacketed combustion chamber construction and resultant high heat dissipation characteristics which are desirable when utilizing a dust-type fuel as the primary fuel source. The primary combustion chamber comprises a long tube **88** extending substantially the length of the boiler **10,** surrounded completely by water for generating steam. Although any type of firetube boiler may be adapted for utilizing dust-type material as the primary fuel, the preferred type is a multi-pass boiler wherein the combustion gases, after being emitted from the chamber **88,** are directed again through the boiler in a series of successive passes through tubes **110, 112** and **114** respectively until the gases are finally vented to the atmosphere through stack **116.**

A potential problem with the use of dust-type fuel, particularly sanderdust waste, is that occasional gross particles such as shavings and splinters much larger than the average dust particles are contained in the fuel. Although the combustion system heretofore described is capable of effecting complete combustion of the normal dust particles, such gross particles will not be completely burned if they are simply permitted to flow through the boiler pursuant to the normal combustion gas flow pattern. Accordingly the boiler **10** is preferably modified by providing a trap in communication with the combustion chamber **88** for catching and retaining such gross particles within the boiler, thereby insuring their complete combustion and preventing the presence of unacceptacle amounts of combustible pollutants in the flue gases. Such trap preferably is included in a boiler extension section **118** adaptable to be inserted on the end of the boiler opposite the dust burner and diffuser assembly **82** between the boiler body and the boiler door **120.** As best seen in FIG. **6,** the boiler extension section **118** is lined with a suitable refractory material **122** and contains an open trap **124** at its bottom into which the gross combustibles may fall by force of gravity after their exit from the combustion chamber **88** and prior to their entry into the multi-pass tube network. Periodically, the accumulation of ashes in the trap **24** may be removed from the trap **124** through removable doors **126, 128.** For a multi-pass boiler of the type shown in FIG. **5,** the boiler extension section must include a baffle such as **130,** corresponding to the baffle **132** in the boiler door **120,** for preserving the original flow pattern of the combustion gases through the boiler.

Operation of the energy generation system is initiated by the actuation of a switch **134** provided on the master control box **106.** This starts a conventional timing sequence built into the master control whereby the blower **86** is first actuated for a predetermined time period in order to purge the boiler of stale air. Inasmuch as the pneumatic conveyor motor **76** is coupled through power line **135** with the boiler blower **86,** it also is actuated concurrently with the blower **86.** After the boiler has been purged, the starting pilot **96** is automatically actuated and the presence of the pilot flame is sensed by the scanner **108.** The scanner sends a signal to the master control **106** in response to the presence of the flame, permitting the fuel feed process to begin. Accordingly the master control **106** actuates valve **104** so as to feed fuel to the supporting pilot **102,** and simultaneously opens dust fuel control valve **136** and supplies power to agitator motor **44** and screw conveyor motors **18** and **70** respectively. This starts the rotation of agitator **38** and screw conveyor **68,** the actuation of screw conveyor **16** being dependent upon the level of the dust fuel in the bin as determined by level sensors **24** and **26** in the manner previously described. Thereafter fuel dust flows through inlet conduit **80** into

the combustion chamber **88,** such flow being variably modulated by controller **56** responsive to boiler pressure sensing device **62,** while the supply of combustion air is concurrently regulated so as to provide proper fuel-air ratio and energy input responsive to boiler demands.

If, during the operation of the boiler, the scanner **108** should indicate the absence of a flame in the combustion chamber, it transmits a signal to the master control **106** which prompty closes dust fuel control valve **136** and supporting pilot valve **104,** and also interrupts power to the respective agitator and screw conveyor motors so as to stop the introduction of fuel into the combustion chamber. The previously described starting cycle is then re-initiated.

If the level of fuel dust in the bin **22** should fall below a predetermined limit, as sensed by a minimum level sensor **138** of the same construction as level sensors **24** and **26,** a signal is transmitted through line **140** to the master control **106** causing interruption of the dust fuel feed to the boiler in the same manner as though the combustion flame were interrupted. In such case the boiler may either be shut down or, if desired, the circuits of the master control **106** can be arranged in a conventional fashion to automatically place the boiler exclusively on an alternate fuel supply, such as natural gas or oil. The purpose of interrupting the dust fuel supply prior to the complete emptying of the bin **22** is to insure that, when the problem of resupplying the bin with fuel is eventually corrected, there will be an immediate fuel supply still available in the bin to permit the normal operation of the boiler starting cycle.

The use of dust-type fuels other than sanderdust, for example coal dust, in a system embodying the foregoing fuel metering and combustion principles is within the scope of the present invention. Moreover, although steam generation is the preferred application of the system, other combustion-type energy generators such as air heaters are also contemplated, with energy demands possibly being indicated by alternative parameters such as temperature. The terms and expressions which have been employed in the foreging abstract and specification are used therein as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features shown and described or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follow.

What is claimed is:

1. Apparatus for adapting a combustion-type energy generation system to utilize primarily dust-type fuel in the combustion chamber of said system, said apparatus comprising:

a. a metering bin for receiving dust-type fuel of variable density from a storage area preparatory to the introduction of said fuel into said combustion chamber;

b. agitating means within said bin for homogenizing said dust fuel in said bin, thereby equalizing the density thereof; and

c. metering means for discharging said homogenized dust fuel from said bin at a predetermined mass flow rate preparatory to said fuel's introduction into said combustion chamber, said metering means including means for preventing any compaction of said dust fuel during said metering thereof to a density greater than that of said homogenized fuel in said bin, so as to insure against any uncontrolled variation in said predetermined mass flow rate of said fuel.

2. The apparatus of claim **1** wherein said metering means includes means for varying said predetermined mass flow rate of said fuel from said metering bin automatically in response to variations in energy demand of said energy generation system.

3. Apparatus for adapting a combustion-type energy generation system to utilize primarily dust-type fuel in the combustion chamber of said system, said apparatus comprising:

a. a metering bin for receiving dust-type fuel of variable density from a storage area preparatory to the introduction of said fuel into said combustion chamber;

b. agitating means within said bin for homogenizing said dust fuel in said bin, thereby equalizing the density thereof;

c. metering means for discharging said homogenized dust fuel from said bin at a predetermined mass flow rate preparatory to said fuel's introduction to said combustion chamber, said metering means including means for preventing any compaction of said dust fuel during said metering thereof to a density greater than that of said homogenized fuel in said bin, so as to insure against any uncontrolled variation in said predetermined mass flow rate of said fuel;

d. said dust fuel metering means comprising a group of paddles adjacent the bottom of said bin, said paddles being equally spaced radially about a common drive shaft for rotating said paddles in unison, said bin having a discharge opening formed therein below said paddles and in juxtaposition therewith for periodically discharging from said bin predetermined mass increments of said fuel from between successive pairs of said paddles as said paddles rotate above said opening.

4. The apparatus of claim **3** wherein said fuel dust metering means further comprises a screw conveyor located beneath said discharge opening for receiving said perodic fuel increments and transforming them into a continuous stream of dust fuel, said screw conveyor having sufficient volumetric capacity in relation to the mass flow rate of said fuel increments to transport said dust fuel without causing simultaneous compaction thereof.

5. The apparatus of claim **3** including a movable gate for varying the size of said discharge opening, and controller means for operating said gate automatically in response to variations in energy demand of said energy generation system.

6. The apparatus of claim **3** wherein said agitating means comprises said paddles.

7. Apparatus for adapting a combustion-type energy generation system to utilize primarily dust-type fuel in the combustion chamber of said system, said apparatus comprising:

a. a metering bin for receiving dust-type fuel of variable density from a storage area preparatory to the introduction of said fuel into said combustion chamber;

b. agitating means within said bin for homogenizing said dust fuel in said bin, thereby equalizing the density thereof;

c. metering means for discharging said homogenized dust fuel from said bin at a predetermined mass flow rate preparatory to said fuel's introduction to said combustion chamber, said metering means including means for preventing any compaction of said dust fuel during said metering thereof to a density greater than that of said homogenized fuel in said bin, so as to insure against any uncontrolled variation in said predetermined mass flow rate of said fuel; and

d. sensor means in said metering bin for sensing the quantity of said dust fuel within said bin, and means automatically responsive to said sensor means for controlling the influx of said fuel into said metering bin from said storage area.

8. The apparatus of claim **7** wherein said sensor means includes a first level sensor for interrupting said influx of fuel when the height of said fuel in said bin reaches a predetermined limit, and a second level sensor for starting said influx of fuel when the height of said fuel in said bin falls below a predetermined limit.

9. Apparatus for adapting a combustion-type energy generation system to utilize primarily dust-type fuel in the combustion chamber of said system, said apparatus comprising:

a. a metering bin for receiving dust-type fuel of variable density from a storage area preparatory to the introduction of said fuel into said combustion chamber;

b. agitating means within said bin for homogenizing said dust fuel in said bin, thereby equalizing the density thereof;

c. metering means for discharging said homogenized dust fuel from said bin at a predetermined mass flow rate preparatory to said fuel's introduction to said combustion chamber, said metering means including means for preventing any compaction of said dust fuel during said metering therof to a density greater than that of said homogenized fuel in said bin, so as to insure against any uncontrolled variation in said predetermined mass flow rate of said fuel; and

d. a minimum level sensor within said bin and means responsive to said minimum level sensor for interrupting the discharge of said dust fuel from said bin whenever the height of said fuel in said bin falls below a predetermined limit.

10. The apparatus of claim **9** including means responsive to said minimum level sensor for automatically introducing a fuel other than said dust fuel into said combustion chamber concurrently with the interruption of said fuel discharge from said bin.

11. The apparatus of claim **1** including plow means within said bin for maintaining the height of said dust fuel substantially level throughout the entirety of said bin so as to promote the equalization of said fuel density within said bin.

12. The apparatus of claim **1** including a pneumatic conveyor for receiving said metered dust fuel from said metering means and transporting said fuel suspended in a supporting air stream to said combustion chamber.

13. Apparatus for adapting a combustion-type energy generation system to utilize primarily dust-type fuel in the combustion chamber of said system, said apparatus comprising:

a. a metering bin for receiving dust-type fuel of variable density from a storage area preparatory to the introduction of said fuel into said combustion chamber;

b. agitating means within said bin for homogenizing said dust fuel in said bin, thereby equalizing the density thereof;

c. metering means for discharging said homogenized dust fuel from said bin at a predetermined mass flow rate preparatory to said fuel's introduction to said combustion chamber, said metering means including means for preventing any compaction of said dust fuel during said metering thereof to a density greater than that of said homogenized fuel in said bin, so as to insure against any uncontrolled variation in said predetermined mass flow rate of said fuel;

d. said energy generation system including scanner means for sensing the presence of a flame in said combustion chamber and said apparatus further comprising valve means adapted to be responsive to said scanner means for selectively interrupting the introduction of said dust fuel into said combustion chamber in response to the sensing of any interruption of said flame by said scanner means.

14. Apparatus for adapting a combustion-type energy generation system to utilize primarily dust-type fuel in the combustion chamber of said system, said apparatus comprising:

a. a metering bin for receiving dust-type fuel of variable density from a storage area preparatory to the introduction of said fuel into said combustion chamber;

b. agitating means within said bin for homogenizing said dust fuel in said bin, thereby equalizing the density thereof;

c. means defining a discharge opening formed adjacent the bottom of said bin;

d. means within said bin for discharging periodic increments of said homogenized dust fuel through said discharge opening; and

e. means coupled with said discharge opening for receiving said periodic fuel increments and transforming said fuel increments into a continuous stream of said dust fuel.

15. The apparatus of claim **14** including means for controllably varying the size of said discharge opening.

16. The apparatus of claim **3** wherein said drive shaft is mounted substantially vertically within said bin and wherein said paddles project laterally from said shaft.

17. The apparatus of claim **1** including a diffuser adapted to receive said dust fuel from said metering means, said diffuser having at least one dust fuel conduit and a supporting pilot mounted adjacent the face of said diffuser for introducing said dust fuel and a fuel other than said dust fuel respectively into the combustion air pattern emitted from the face of said diffuser.

18. The apparatus of claim **1** including means for adapting a multi-pass firetube boiler having a burner assembly located at one end thereof to utilize said dust-type fuel, said apparatus comprising trap means adapted to be coupled with the interior of said boiler's combustion chamber for retaining within said chamber gross particles which may be present within said dust-type fuel so as to insure complete combustion thereof, said trap means comprising a boiler extension section

adaptable to be inserted between the door and body of said boiler on the end thereof opposite said burner, said extension section having a trap adjacent its bottom portion and interior baffle means for preserving the original combustion gas flow pattern through said firetube boiler.

19. The apparatus of claim **1** wherein said dust fuel metering means comprises a discharge opening formed in said bin at a location below said agitating means, the horizontal cross-section of said bin having substantially no decrease in size from said agitator to said opening.

20. The apparatus of claim **14** wherein the horizontal cross-section of said bin has substantially no decrease in size from said agitator to said opening.

21. The apparatus of claim **14** wherein said means coupled with said discharge opening for transforming said fuel increments into a continuous stream of dust fuel comprises a screw conveyor having sufficient volumetric capacity in relation to the mass flow rate of said fuel increments to transport said dust fuel without causing simultaneous compaction thereof.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,824,937 Dated July 23, 1974

Inventor(s) Leslie C. Turner and Harry Cockreham

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Change the name of the assignee from "Tureo Engineering, Inc." to --Turco Engineering, Inc.--

Abstract, line 10	Change "volumn" to --volume--.
Col. 1 line 39	Change "imcomplete" to --incomplete--.
Col. 5 line 35	After "chute 20," add --thereby--.
Col. 5 line 36	Change "throughtout" to --throughout--.
Col. 5 line 62	Change "throuh" to --through--.
Col. 6 line 67	Change "powdered" to --powered--.
Col. 7 line 54	Change "photelectric" to --photoelectric--.
Col. 10 line 44	Change "perodic" to --periodic--.
Col. 11 line 38	Change "therof" to --thereof--.

Signed and sealed this 5th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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