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(54) **METHOD AND APPARATUS FOR DRYING SOLID FUELS**

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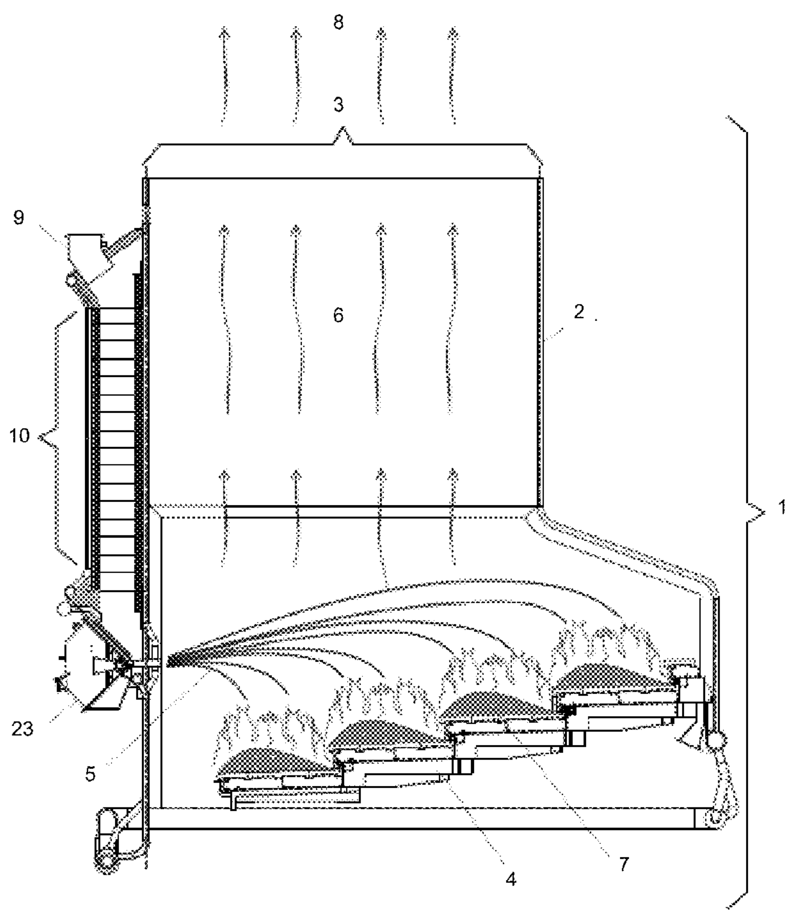
(57) **ABSTRACT**

A method for drying solid fuels prior to injection and burning in solid fuel boilers is described. High moisture content solid fuels such as bark, sludge, wet coal, etc. must be dried before they can burn. Embodiments of the present invention incorporates a fuel delivery chute integrated with the boiler wall using a flow of combustion gasses and radiant heating to partially dry the solid fuel before it reaches the combustion zone of the boiler. The combustion gasses are drawn through the delivery chute by means of the flowing fuel and air jet inductors that then blows the combustion gasses back into the boiler. A refractory wall separates the fuel chute from the boiler proper, is heated by the combustion in the boiler, and radiates heat to the fuel falling through the fuel chute.



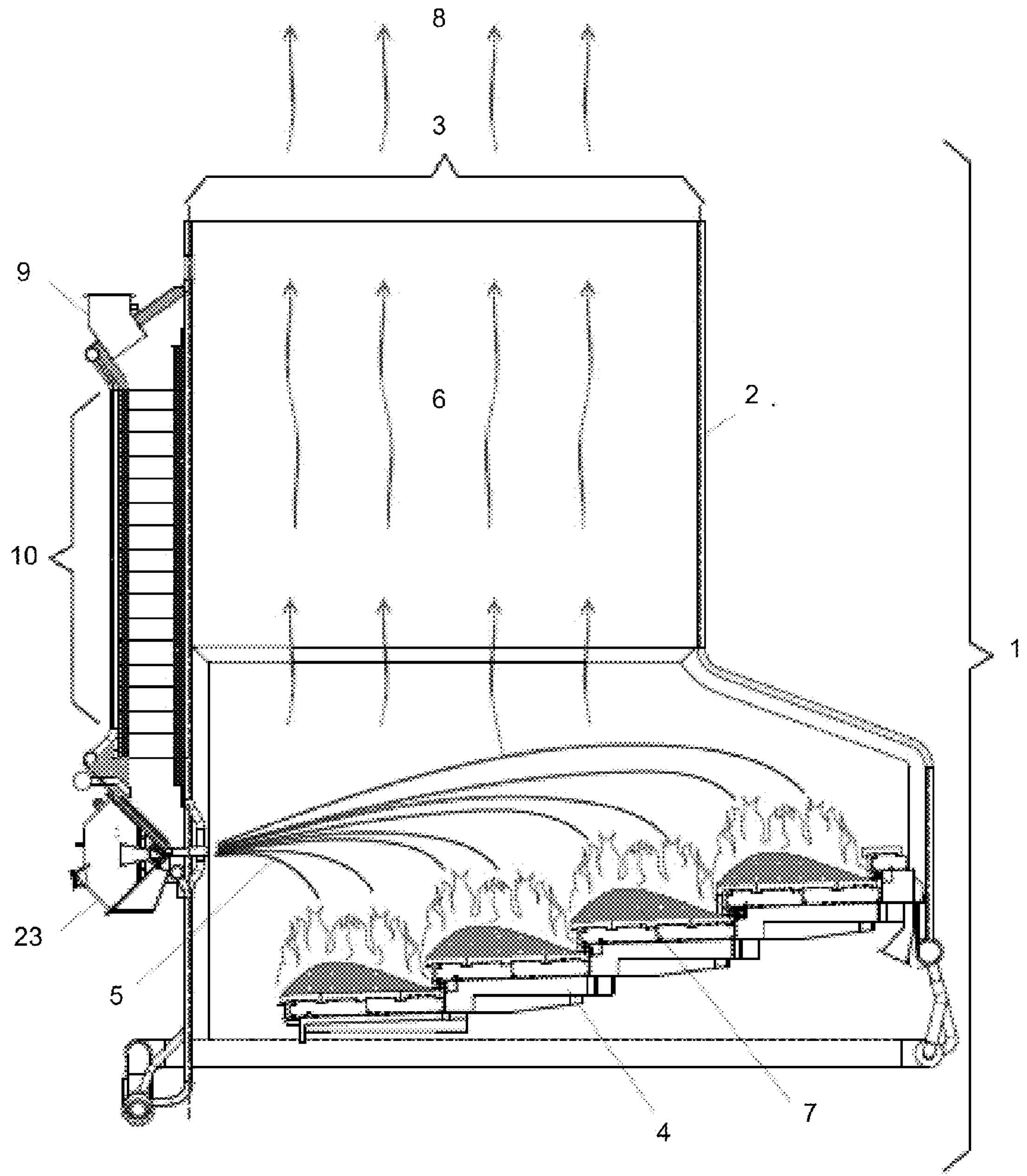


Figure 1

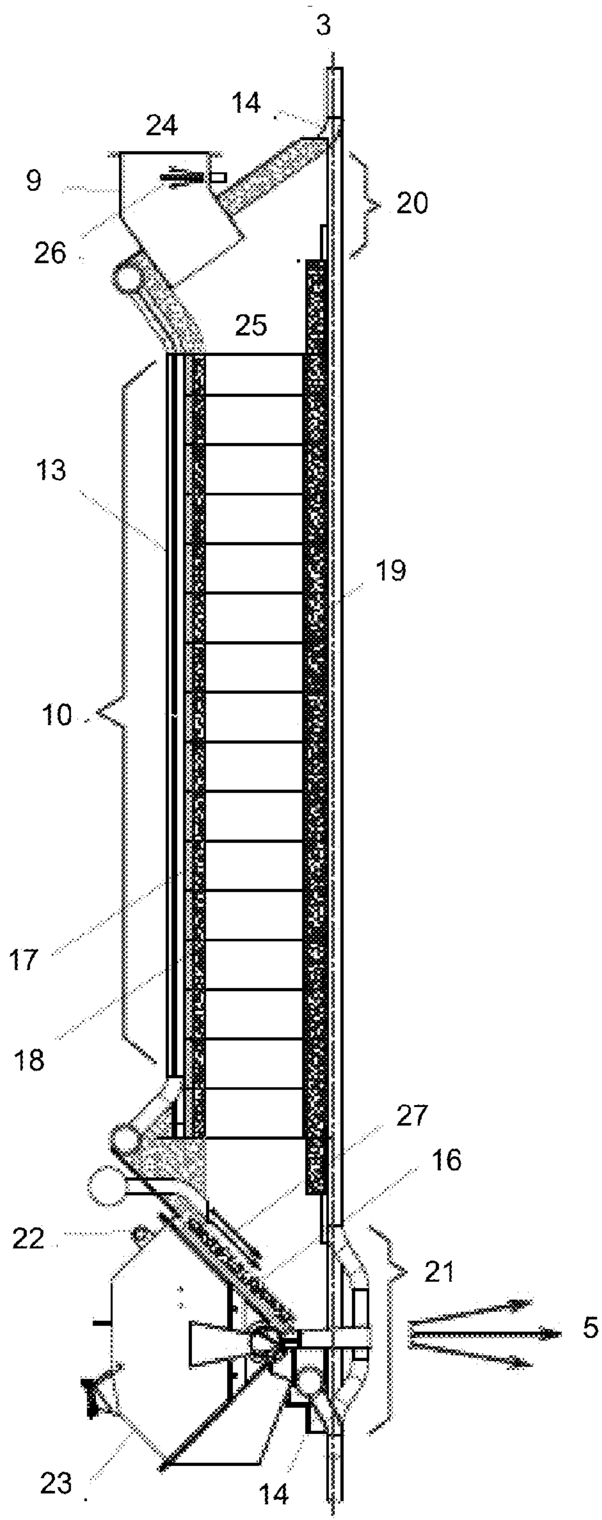


Figure 2

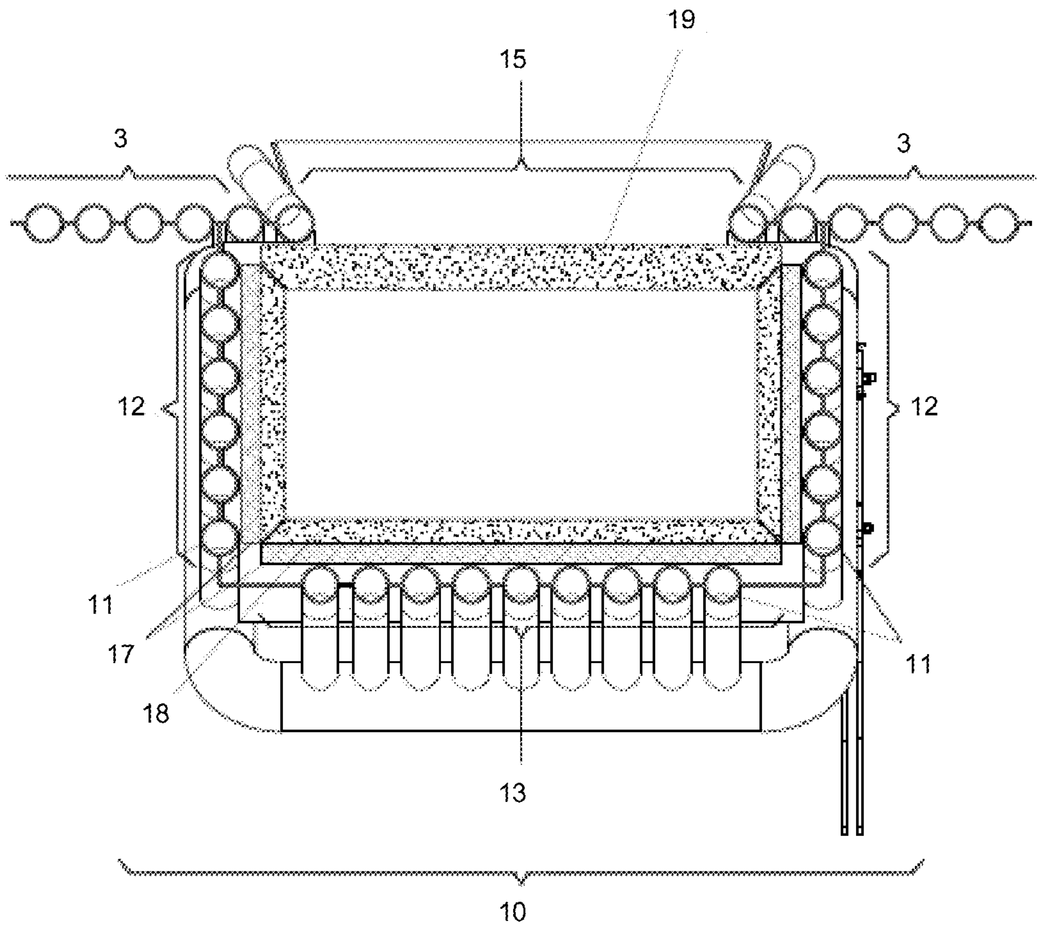


Figure 3

METHOD AND APPARATUS FOR DRYING SOLID FUELS

[0001] The present application is a continuation of International Patent Application No. PCT/US12/50610 filed Aug. 13, 2012, which claims priority from U.S. Provisional Application 61/522,939, filed Aug. 12, 2011, which are hereby incorporated by reference.

TECHNICAL FIELD OF THE INVENTION

[0002] The present invention relates to solid fuel boilers, and in particular, to a fuel chute that removed moisture from the solid fuel before the fuel enters the boiler.

BACKGROUND OF THE INVENTION

[0003] Solid fuel boilers are commonly used by industry and utilities to generate steam for process requirements and to generate electricity. These boilers burn bark, coal, sludge, wood waste, refuse, tires, and other organic materials, often in combinations, and with fossil fuels. Generally the organic materials have high moisture contents and are stored outdoors where they are often wet from rain water or, in the case of sludge, reclaimed from wastewater treatment facilities. In some cases some of the moisture is removed before the fuel is delivered to the boiler by means of mechanical presses or drying chambers using hot gasses from the discharge of the boiler. These practices are often troublesome, expensive, risky, and not particularly efficient. For these reasons these methods are not universally employed. Even with these methods the fuels still contain significant moisture content. In any case all of the water in the fuel must be removed during the combustion process and when the fuels are wet the combustion process can be unstable and inefficient. The situation is further exacerbated by changing moisture contents of the fuel (e.g., from rain) that introduces variations into the combustion process and make it more difficult to operate the boilers.

[0004] Solid fuel boilers in this application are typically constructed as large boxes (up to 100 m2 or more floor area) and constructed of heavy steel tubing forming walls of the box, typically referred to as the front, sides, and rear walls. The tubing is typically 2½" (63.5 mm) or 3" (76.2 mm) outside diameter, arrayed in parallel relationship forming flat panels with the tubes running vertically. The tubes are typically spaced apart ½" to 1" (12 mm-25 mm) with a steel membrane bridging the gap. The whole assembly is seal welded together forming an air tight structure. The boiler walls, or tube panels, run vertically to the top of the boiler, up to 30 m or more tall. The walls are fed re-circulating water by headers at their lower extremity. Typically the front wall tubes are bent over more or less horizontally to form the roof of the boiler and the side walls end in relieving headers feeding back to a steam drum. The rear wall either ends in a header or feeds directly into the steam drum. In order to feed fuel and combustion air into the boiler, and for other purposes, the boiler tubes are bent apart to form openings in the tube panel.

[0005] The bottom of the boiler may be arranged as a grate type boiler, fluidized bed boiler, or other arrangement. Grate type boilers include traveling grates, vibrating grates, tilting grates, and hydro-grates. Typically the grates cover the bottom of the boiler and are made of heavy cast iron components with slots for combustion air to rise through the grate from a plenum below. The solid fuel lands on the grate and burns there. The ash is dumped off of the grate as the grate moves (rotates like a tank tread), vibrates, or tilts (in sections). Fluidized bed boilers generally have a mass of sand or other media through which a stream of air or boiler flue gas is percolated to fluidize the bed. The fluidized bed acts as a heat sink, fuel drying system, turbulent fuel/air mixing system, fuel distribution system, and means for separating fuel and ash in the boiler. Additional combustion air ports, typically called "over fired air" (OFA) are arranged to blow air in above the grate or fluidized bed to help complete the combustion. In all of these arrangements if the fuel is not properly dried poor combustion can result leading to poor operational efficiencies and high environmental emissions.

[0006] In common practice the solid fuel is fed by gravity through large chutes, steeply mounted and about two feet (600 mm) or more square, from a hopper and/or conveyor system above, to the lower portion of the boiler just above the grate or fluidized bed. There are typically multiple chutes penetrating a wall or walls of the boiler. A solid fuel distributor is often integral with and at the bottom of the chute right at the interface with the boiler wall. Mechanical distributors and pneumatic distributors are commonly used. Grate type boilers generally require some type of fuel distribution whereas fluidized bed boilers can be run without them as the fluidized bed can distribute the fuel, albeit inefficiently. Typically the fuel slides down the chute and enters the boiler with high residual moisture content (up to 50% or more). The water in the fuel inhibits the combustion in the furnace often requiring the continual use of supplemental fossil fuels to provide additional heat to compensate for the moisture. It is also very common for the load rate on these boilers to change frequently in reaction to changing steam demands. Inconsistent and high moisture content of the fuels makes it difficult for the boiler to respond effectively to the required load changes. This requires, again, the use of supplemental fossil fuels to improve the response of the boiler to load rate changes. Fossil fuels are typically used to start these boilers but continual use of fossil fuels is extremely expensive. Fluidized beds can help to compensate for varying moisture contents and load rates because they act as heat sinks, but they are limited in their heat release rate and can have significant operational and mechanical problems such as sand sintering and sand erosion and they require a sand reclamation system.

[0007] There is great demand for a simple means to dry solid fuels so that they are delivered to the boiler combustion chamber ready to burn. Such a system must be inexpensive to install and operate, reliable, effective, and safe. The present invention, embodiments of which are described below, addresses this challenge and incorporates all of these features.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a sectional side elevation of the lower part of the combustion chamber of a water tube boiler with embodying the present invention.

[0009] FIG. **2** is a partial sectional side view elevation of the boiler of FIG. **1**. To the right of the drawing is the interior of the boiler where the fuel is burned. To the left of the drawing is outside the boiler.

[0010] FIG. **3** is a sectional plan view through the embodiment of FIGS. **1** and **2**, identifying the various components of the boiler.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0011] Referring to FIG. **1**, the lower part of the combustion chamber **1** of a water tube boiler is constructed of heavy gauge vertically aligned steel tubes **2** forming tube walls **3** enclosing the combustion chamber on four sides. The bottom of the boiler may be arranged with a traveling grate, vibrating grate, fluidized bed, or stepped floor **4** as shown (reference U.S. patent application Ser. No. 12/557,085). Bulk fuel such as bark may be injected **5** from a fuel distributor **23** and land on the floor **4** and burn there. Combustion gases **6** are emitted from the burning fuel **7** and rise and exit the combustion chamber at **8** on their way to the convective heat transfer sections of the boiler (not shown).

[0012] Referring now to FIG. **2** and FIG. **3**, an upper fuel chute **9** descends from above at a steep angle and intersects vertical chute **10** with a vertical dimension determined by the available height of the boiler or other limiting factors. In general vertical chute **10** is made as tall as possible. Vertical chute **10** is arranged immediately adjacent to the boiler tube wall **3** and is made from boiler tubes **11** arranged to form a three sided chute with two parallel sides **12** perpendicular to boiler tube wall **3** and a back side **13** parallel to but offset from the boiler tube wall **3** that bridges between the parallel sides **12**. The boiler tubes **14** in the plane of tube wall **3** that are between the two parallel sides **12** are bent out of the plane of the tube wall **3** to feed water to tubes comprising the walls **12** and **13** of the vertical chute **10**. When these tubes are bent out of the plane of tube wall **3** an opening **15** is created in tube wall **3** exposing the interior of the vertical chute **10** to the combustion chamber. Vertical chute **10** terminates at its bottom in a sloping floor **16** descending back to the plane of tube wall **3**. The sides **12** and back **13** of vertical chute **10** are lined with one or more layers of insulating material **17** and/or refractory **18**. Insulating material **17** and refractory material **18** may be cast in place or prefabricated as boards or tiles. High temperature resistant refractory **19** is arranged to bridge gap **15** and close off most of vertical chute **10** from combustion chamber **1**. Refractory **19** may be cast in place or prefabricated as blocks or tiles. Refractory **19** is arranged to leave openings **20** and **21** at the top and bottom respectively between the combustion chamber **1** and vertical chute **10**. The floor **16** of vertical chute **10** is lined on the upper side with an abrasion resistant refractory or ceramic material **22**. A fuel distributor **23** can be arranged to fit at the bottom of vertical chute **10**. Nozzles **26** and **27** may be incorporated to inject recirculated flue gas as described below.

[0013] Wet fuel enters chute **9** at point **24** and flows into vertical chute **10** at point **25**. The fuel then falls through vertical chute **10** until it lands on sloping floor **16** and slides down to the fuel distributor **23** and is then injected through opening **21** into the boiler at **5**. The motion of the falling fuel will induce a downward flow of combustion gases through vertical chute **10**. The gases will enter the chute at the top through opening **20** and exit the chute at the bottom through opening **21**. The hot combustion gas (around 2000 F) will partially dry the fuel as it is falling through vertical chute **10**. Refractory **19** will also be heated by the combustion in combustion chamber **1** and reach an equilibrium temperature around 2000 F. Refractory **19** will then radiate to the interior of vertical chute **10** increasing the heat transfer to the falling fuel and further drying the fuel. The liberated water vapor will exit vertical chute **10** through the lower opening **21** with the flowing boiler gas and fuel. Nozzles **26** are arranged to inject recirculated flue gas into the top of chute **9** to purge high temperature gases that may accumulate there and to help induce the flow of combustion gases through vertical chute **10**. Nozzles **27** are located to help blow the fuel down to fuel distributor **5** and to help induce the flow of combustion gas through vertical chute **10**. These nozzle or other nozzles may be installed in other advantageous locations. The recirculated flue gas is tapped off of the flue gas ducts preferably downstream of all heat transfer surfaces, pollution control equipment, and fans. It is then routed through a booster fan and injected at a higher pressure through nozzles **26** and **27**.

[0014] Embodiments of the present invention share some characteristics with the second embodiment described in patent application Ser. No. 12/471,081, filed May 22, 2009 by some of the same inventors. In that application the second embodiment describes a fuel chute for drying fuel in which an upper chute controls the flow of fuel to a lower chute, the lower chute having three sides made from boiler tubes and the fourth side open to the interior of the boiler. In that embodiment the fuel falling through the lower chute is exposed to the combustion in the boiler and heated by direct radiation and whatever combustion gasses the fuel contacts. In some embodiments of the present invention, the three sided chute is separated from the interior of the boiler by the refractory wall described above. The refractory wall is open at the top and bottom and combustion gasses are induced to flow from the boiler into the chute at the top and back into the boiler at the bottom, thereby promoting the mixing of the hot gasses with the fuel. The refractory wall is in place to contain the falling fuel inside the chute so that it will flow properly to the fuel distributor. The refractory wall has the second function of absorbing heat from the combustion inside the boiler and then radiating heat to the fuel inside the chute. Embodiments of the present invention also incorporates refractory lining of the lower chute for insulation and abrasion resistance; gas-jets to help induce the flow of gases through the chute and promote the movement of the fuel and cooling of the upper chute; a refractory or ceramic lined sloping floor; and an integral fuel distributor.

[0015] It will be apparent to those skilled in the art that many changes and modifications may be made to the system described above without departing from the invention in its broader aspects. The appended claims are therefore intended to cover all such changes and modifications as fall within the true spirit and scope of the invention.

We claim as follows:

1. An apparatus for drying fuel entering a solid fuel boiler having a combustion chamber within tube walls carrying fluid to be heated by combustion in the combustion chamber, the apparatus comprising:

a fuel chute for transferring solid fuel to the combustion chamber, the chute having an interior region through which fuels falls, the interior region being separated from the interior of the combustion chamber by a refractory material that transfers heat from the combustion chamber to the solid fuel as it drops in the chute to reduce the moisture content of the solid fuel before it reaches the combustion chamber;

an entrance for inserting solid fuel into the fuel chute; and

an exit in the fuel chute for dispensing solid fuel into the combustion chamber;

the chute wall transferring heat to the solid fuel as it drops in the chute to reduce the moisture content of the solid fuel before it reaches the combustion chamber.

2. The apparatus of claim **1** in which the refractory material is heated by the combustion chamber and heats the fuel by radiation.

3. The apparatus of claim **1** in which the refractory material comprises of tiles, board, or other prefabricated components.

4. The apparatus of claim **1** in which the refractory material is a cast in place material.

5. The apparatus of claim **1** in which the refractory material reaches an equilibrium temperature of at least 2000° F.

6. The apparatus of claim **1** in which solid fuel includes bark, coal, sludge, wood, waste, refuse, tires, or fossil fuels having a residual moisture content of 50% or greater prior to entering the chute.

7. The apparatus of claim **1** in which the chute is positioned between a tube wall and the combustion chamber.

8. The apparatus of claim **1** in which the interior of the chute is lined on four sides with refractory material.

9. The apparatus of claim **1**, further comprising a fuel distributor that dispenses fuel to the combustion chamber from the fuel chute.

10. The apparatus of claim **1** in which the fuel chute includes an opening for gas from the combustion chamber to enter the fuel chute, the gas being drawn into the chute by the flow of fuel down the chute and mixing with the fuel as it descends the chute.

11. The apparatus of claim **1**, further comprising a gas nozzle for injecting gas into the portion top of the chute.

12. A solid fuel boiler including:

tube walls for carrying fluid to be heated;

a combustion chamber for combusting fuel to heat the fluid in the rube walls; and

an apparatus for drying fuel in accordance with claim **1**.

13. A method for providing solid fuel to a combustion chamber of a solid fuel boiler, comprising:

inserting the fuel into a gravity fed chute through an entrance in the gravity fed chute;

reducing the moisture content of the solid fuel while the fuel is passing through the gravity fed chute by heating the fuel in the chute by radiation from at least one wall of the gravity fed chute that is heated by thermal contact with the combustion chamber; and

delivering the fuel with the reduced moisture content into the combustion chamber.

14. The method of claim **13** further comprising drawing gas from the combustion chamber into the chute near the top of the chute, the gas flowing down the chute with the fuel.

15. The method of claim **13** further comprising injecting gas into the chute near the top to circulate gas at the top of the chute.

16. The method of claim **13** in which reducing the moisture content of the solid fuel while the fuel is passing through the gravity fed chute by heating the fuel in the chute by radiation from at least one wall comprises passing the fuel through a chute that is separated from the interior of the combustion chamber by a refractory material and not by a tube wall.

17. The method of claim **13** in which delivering the fuel includes the fuel dropping onto a sloping floor of the gravity fed chute, the sloping floor lined with abrasion resistant refractory material.

18. The method of claim **13** in which delivering the fuel includes injecting gas into the gravity fed chute to help deliver the solid fuel to the combustion chamber.

19. An apparatus for drying fuel entering a solid fuel boiler having a combustion chamber within tube walls carrying fluid to be heated by combustion in the combustion chamber, the apparatus comprising:

a fuel chute for transferring solid fuel to the combustion chamber, the chute having at least one chute wall in thermal contact with the combustion chamber, the chute wall not being separated from the interior of the combustion chamber by a tube wall;

an entrance for inserting solid fuel into the fuel chute; and

an exit in the fuel chute for dispensing solid fuel into the combustion chamber,

the at least one chute wall transferring heat to the solid fuel as it drops in the chute to reduce the moisture content of the solid fuel before it reaches the combustion chamber.

20. The apparatus of claim **19** in which the at least one chute wall in thermal contact with the combustion chamber comprises a refractory material.

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