US008640655B2

(12) **United States Patent**
Furman

(10) **Patent No.: US 8,640,655 B2**
(45) **Date of Patent: Feb. 4, 2014**

(54) **HIGH EFFICIENCY WOOD OR BIOMASS BOILER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1184 days.

(21) Appl. No.: **12/319,227**

(22) Filed: **Jan. 2, 2009**

(65) **Prior Publication Data**

US 2009/0183693 A1 Jul. 23, 2009

Related U.S. Application Data

(60) Provisional application No. 61/009,787, filed on Jan. 2, 2008.

(51) **Int. Cl.**
F24H 1/00 (2006.01)

(52) **U.S. Cl.**
USPC **122/16.1**; 110/158; 126/286

(58) **Field of Classification Search**
USPC .... 110/158; 126/285 R, 286, 287; 122/16.1
See application file for complete search history.

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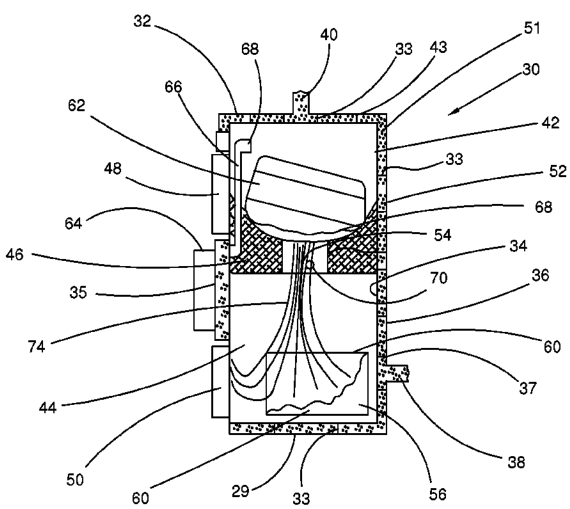
Primary Examiner — Craig Schneider
(74) *Attorney, Agent, or Firm* — Simpson & Simpson, PLLC

(57) **ABSTRACT**

A boiler including a water jacket surrounding upper and lower combustion chambers for receiving heat for heating water or other fluid therein, which chambers are defined by a refractory structure that extends entirely across the inner casing. A vertical passage through the refractory structure provides for flow of combustion gases from the upper to lower combustion chamber. Oxygen is provided through a first forced air inlet to the upper combustion chamber for burning of wood or biomass, and is provided through a forced air passage in the refractory structure and opening into the vertical passage thereby providing at least one second forced air inlet for burning of the combustion gases and particulates passing therethrough. The refractory structure sealingly engages the inner casing in a manner to seal the upper combustion chamber from the lower combustion chamber so that the upper combustion chamber can be made substantially air tight.

13 Claims, 15 Drawing Sheets



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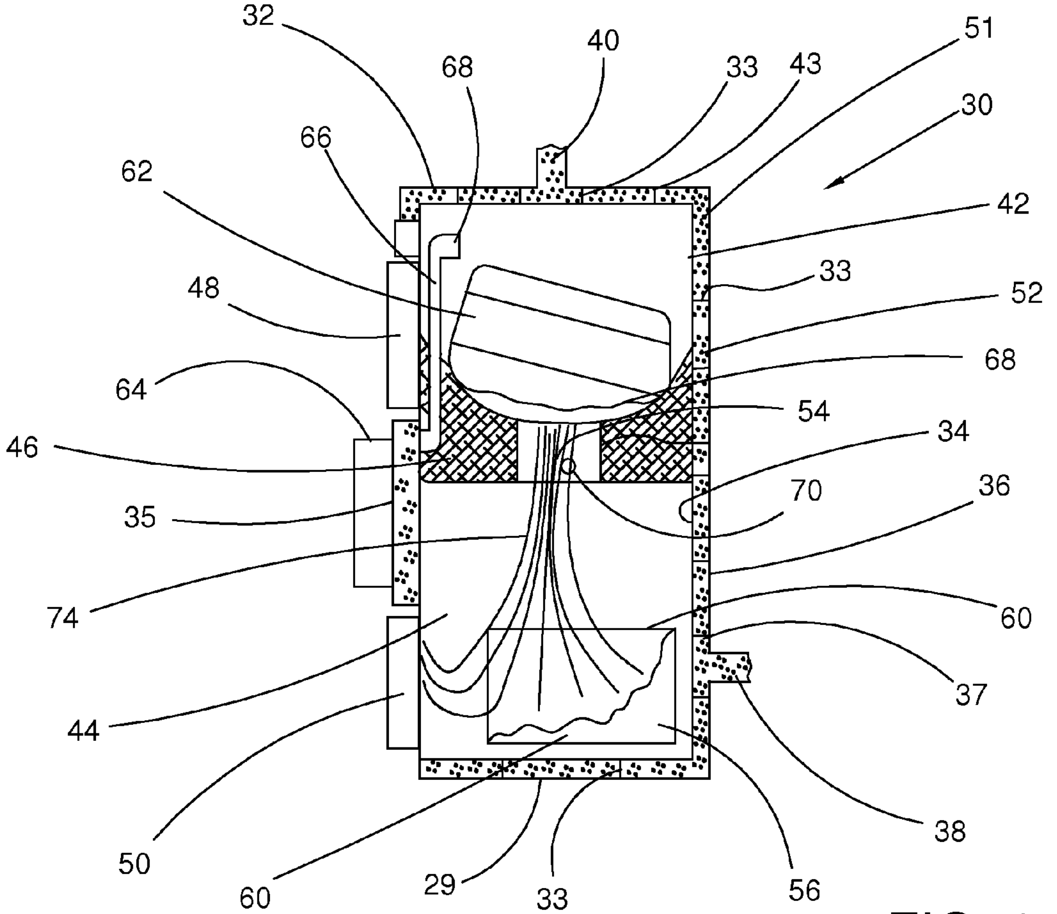
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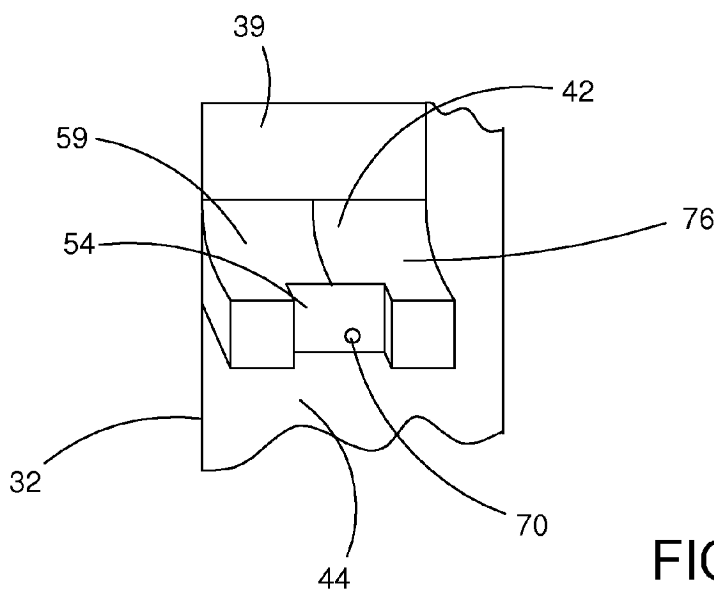
FIG. 1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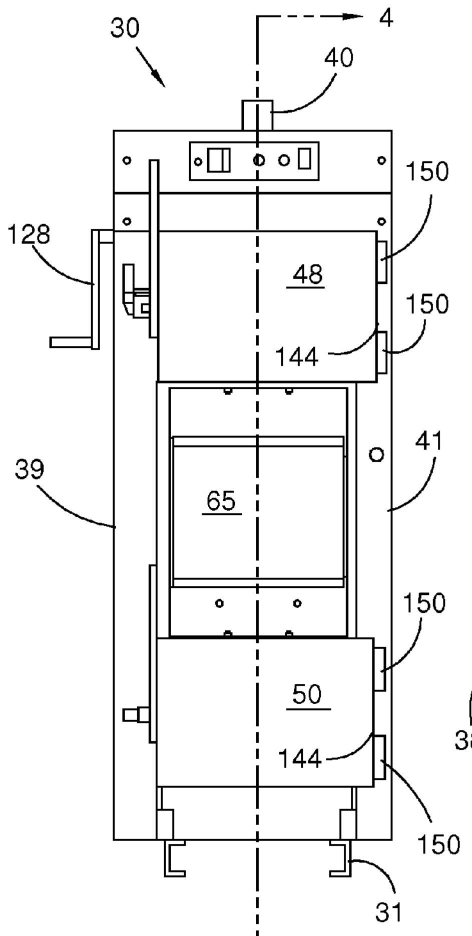
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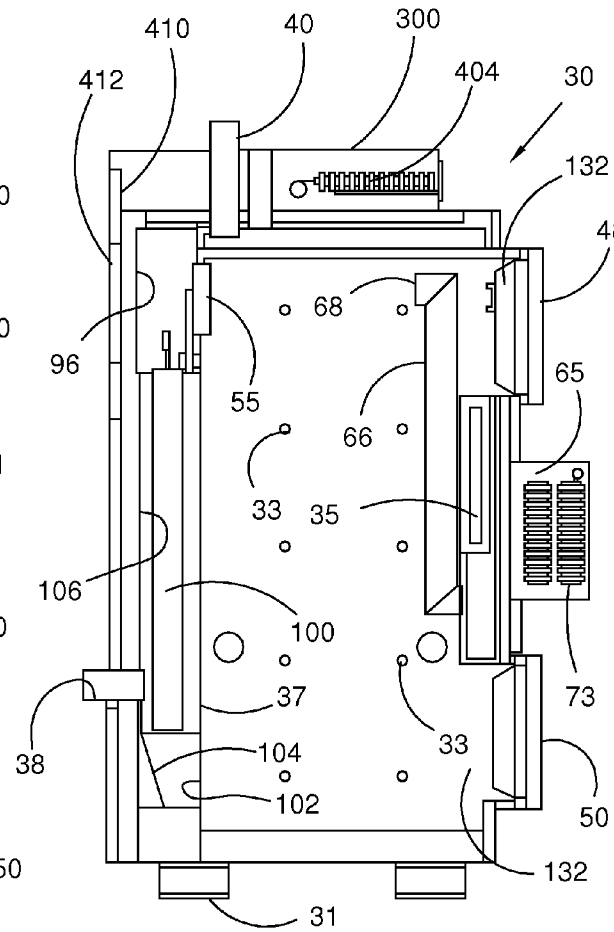
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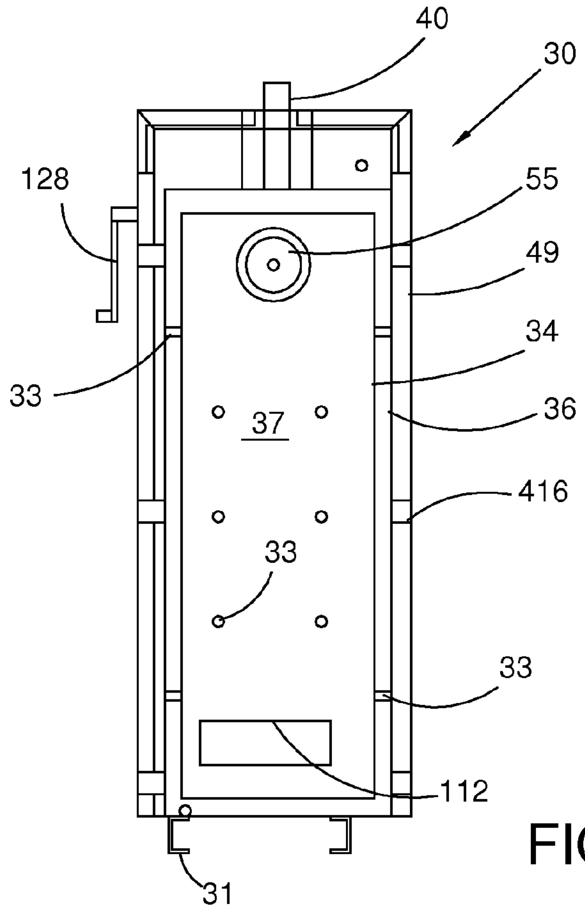
FIG. 4



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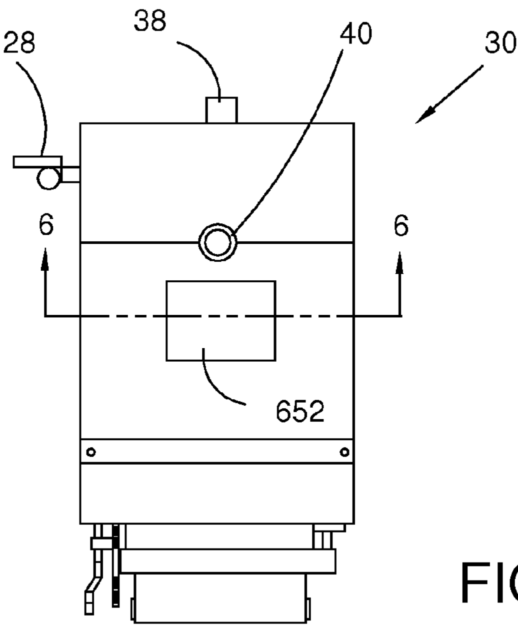

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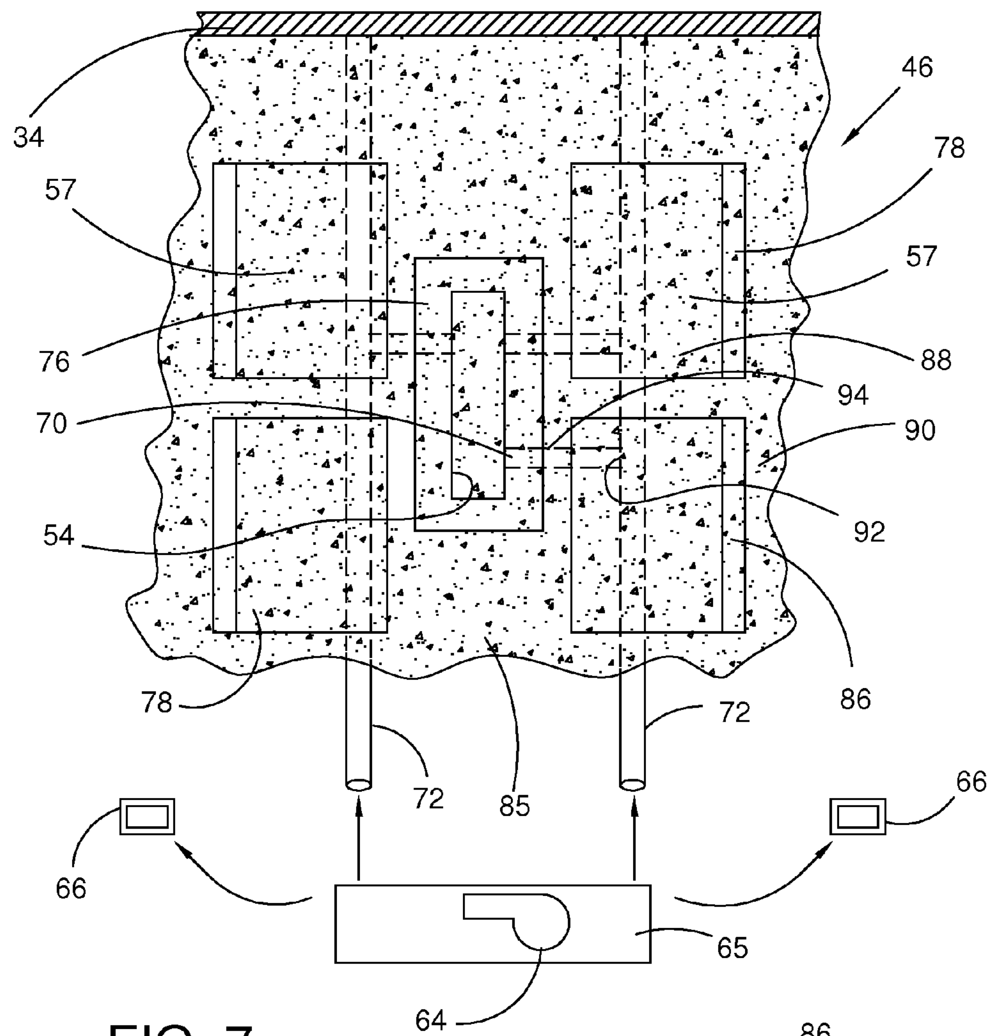
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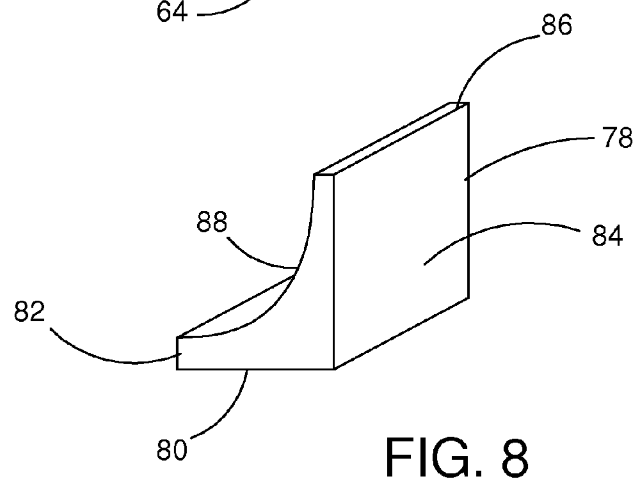
FIG. 7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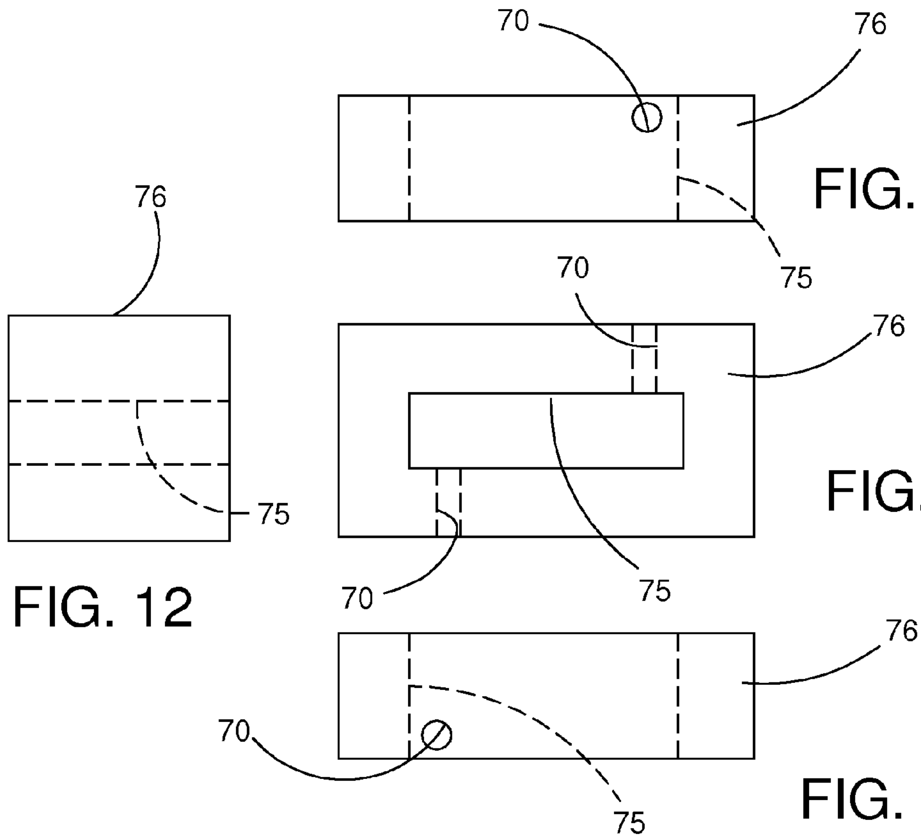
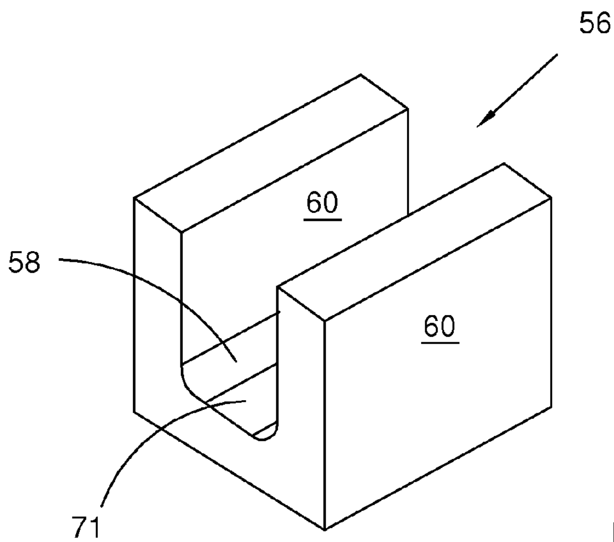


FIG. 10

FIG. 9

FIG. 12

FIG. 11



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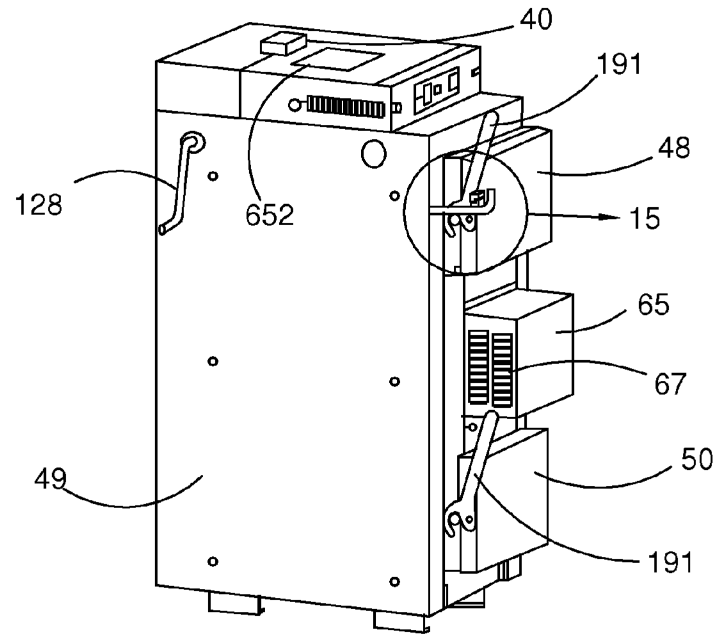
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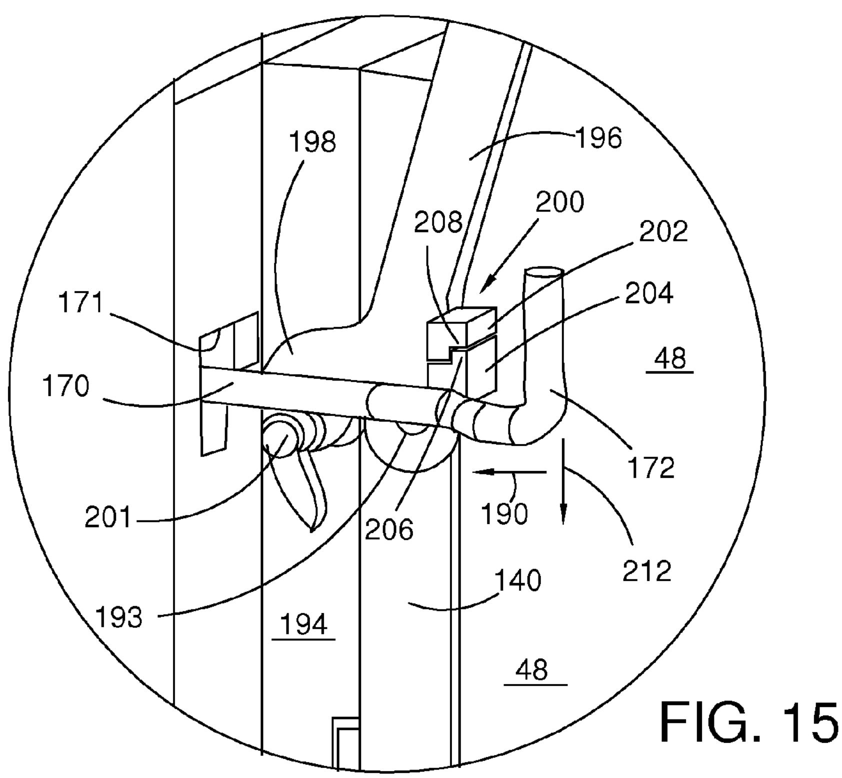
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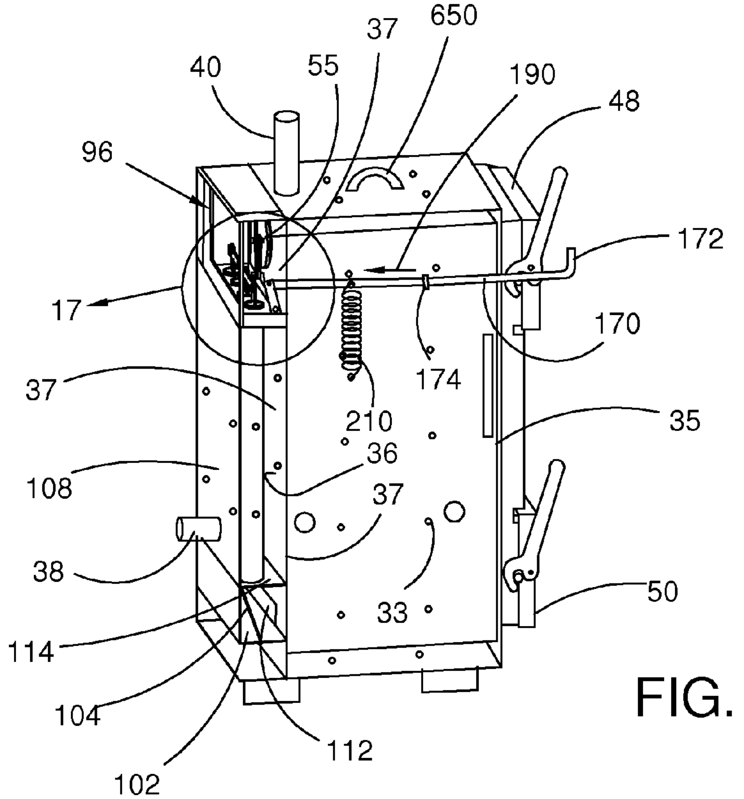
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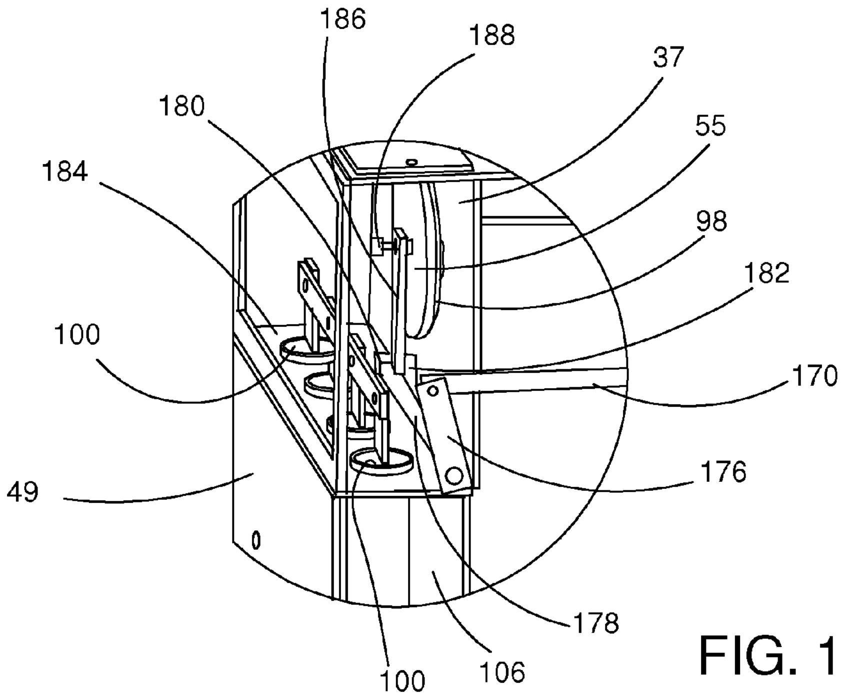
FIG. 16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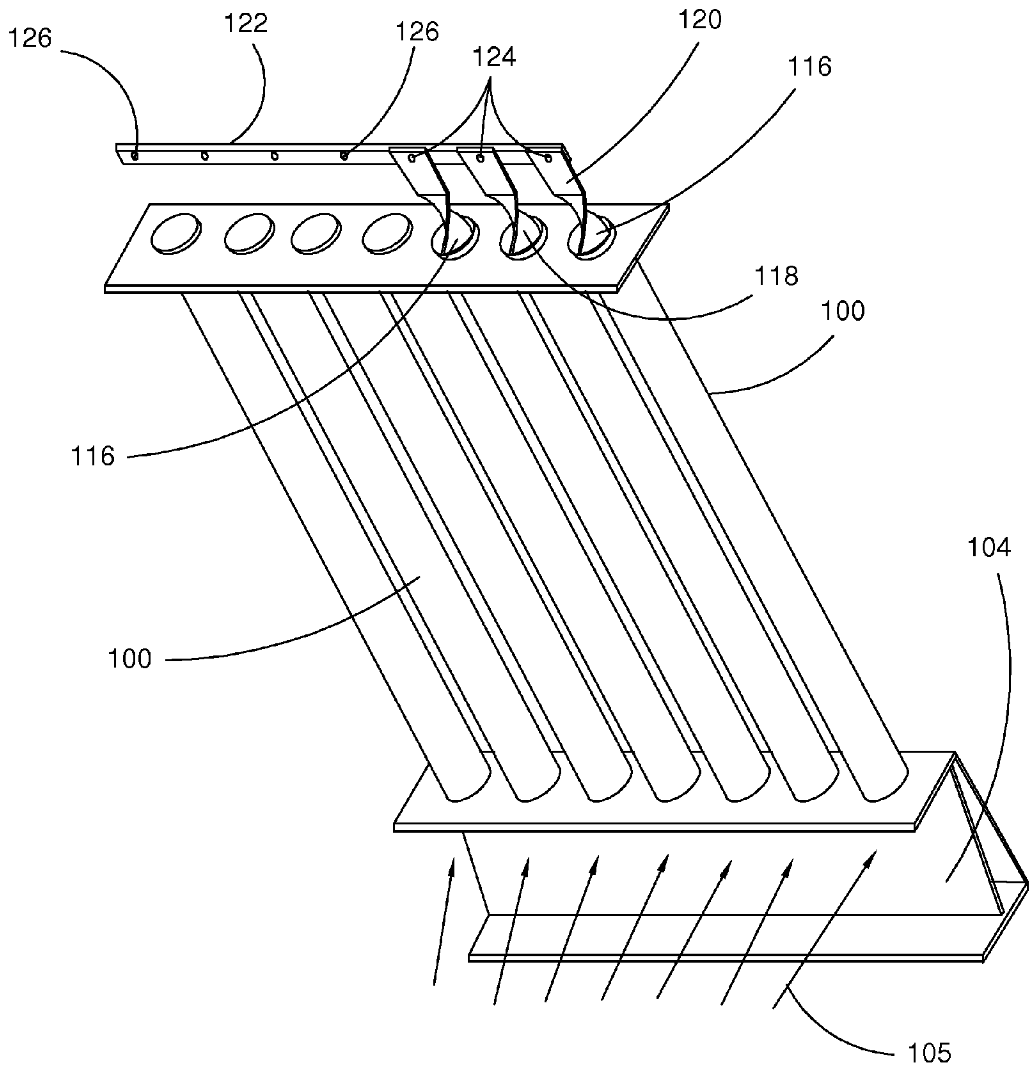

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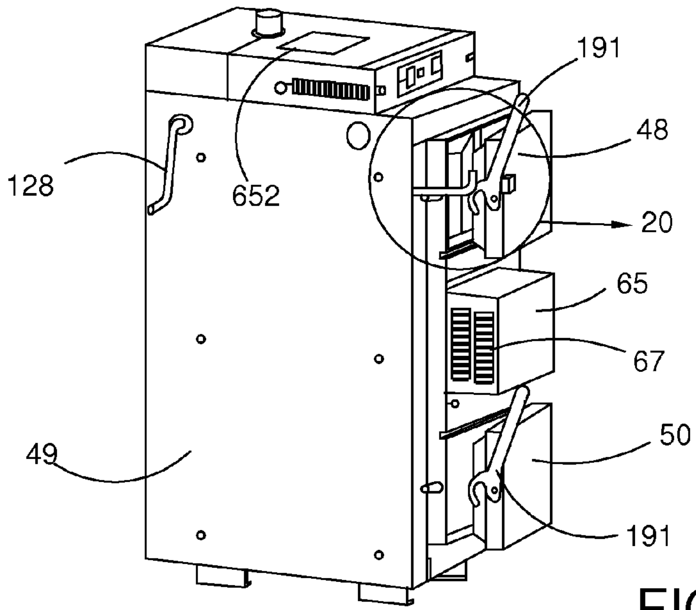
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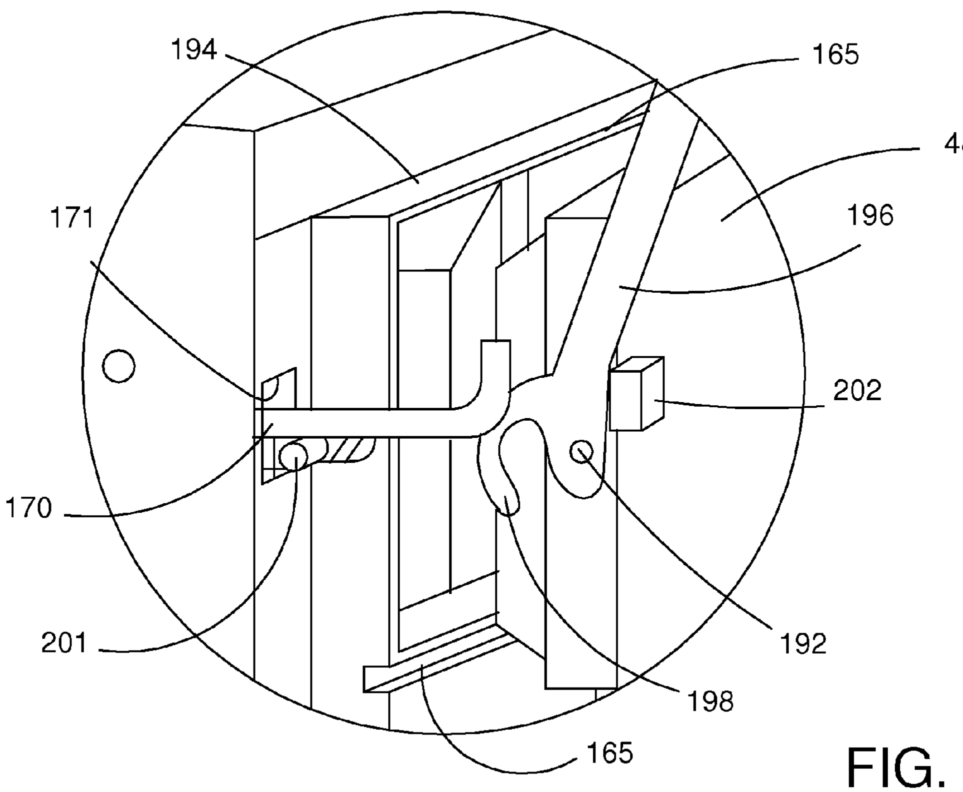
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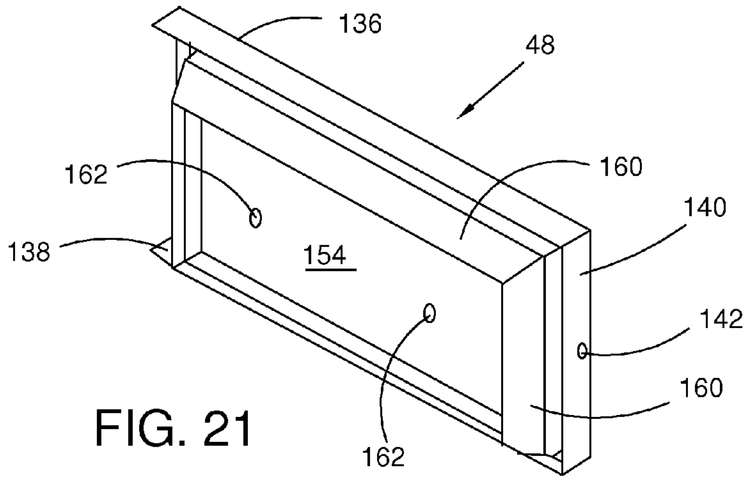

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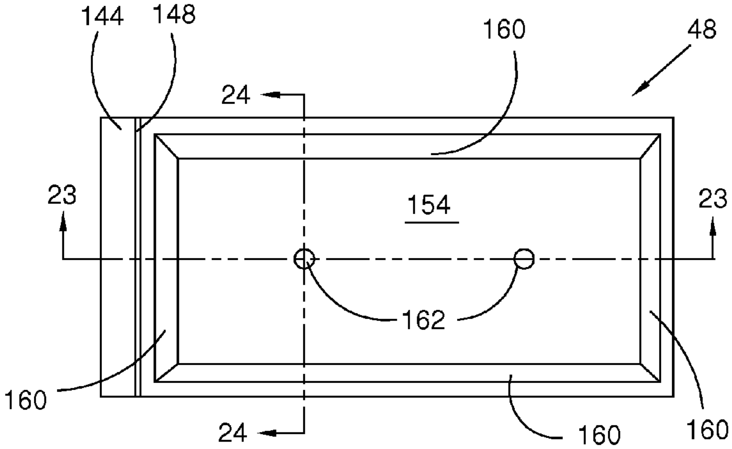

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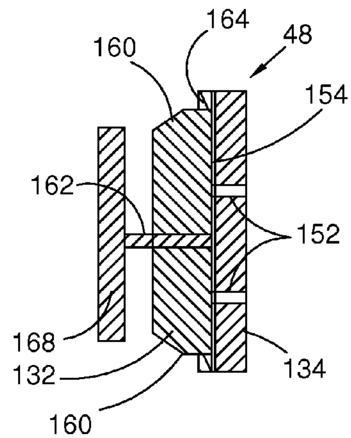

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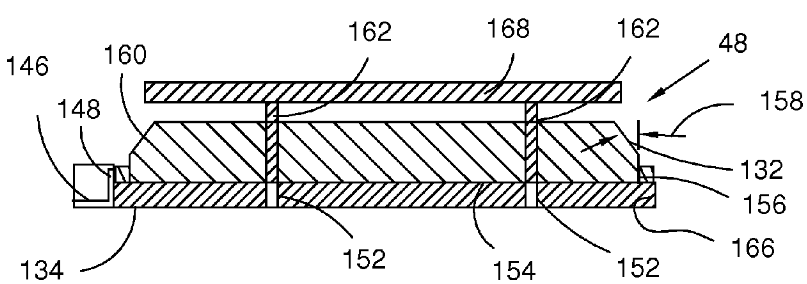

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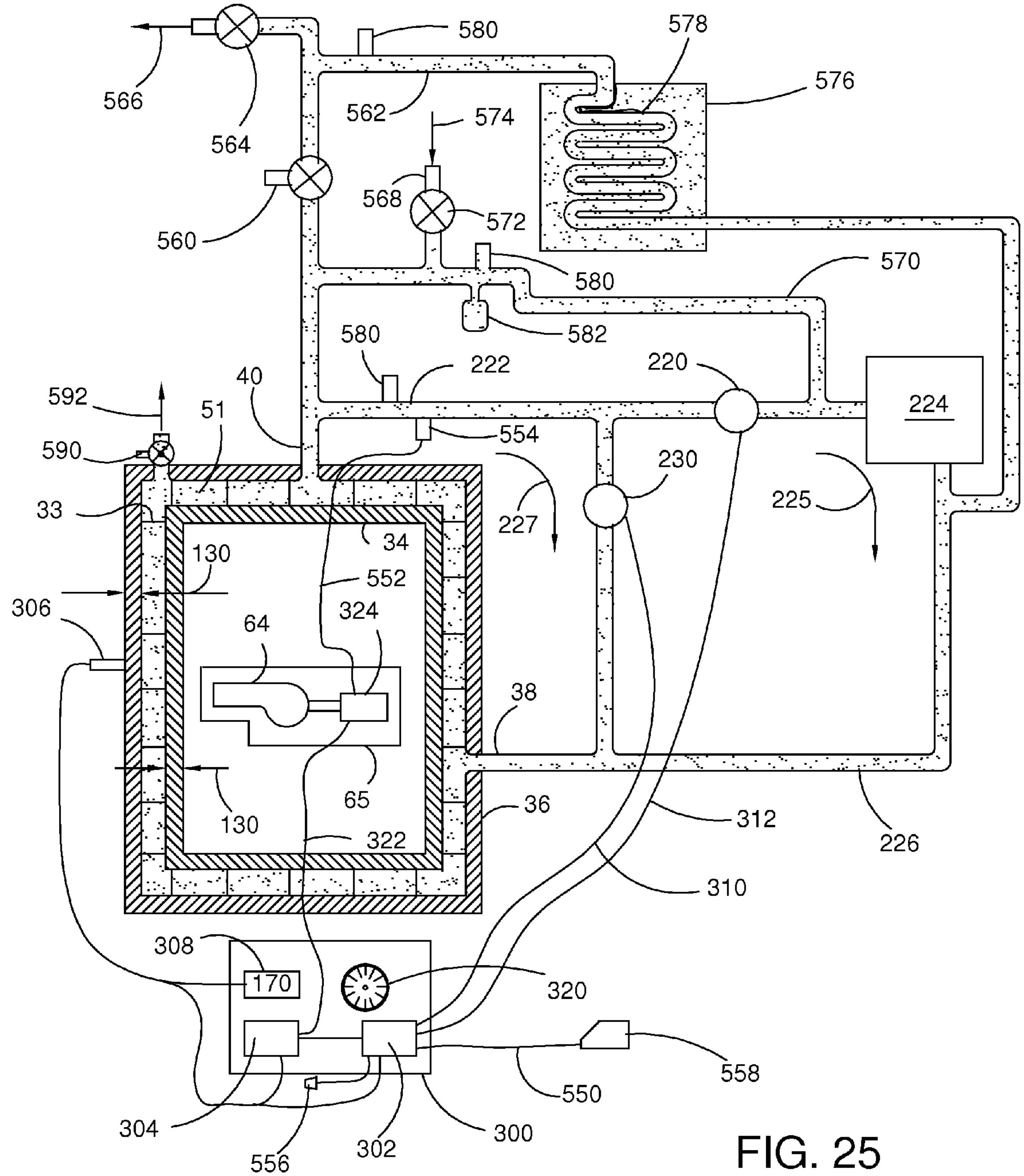
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FIG. 25

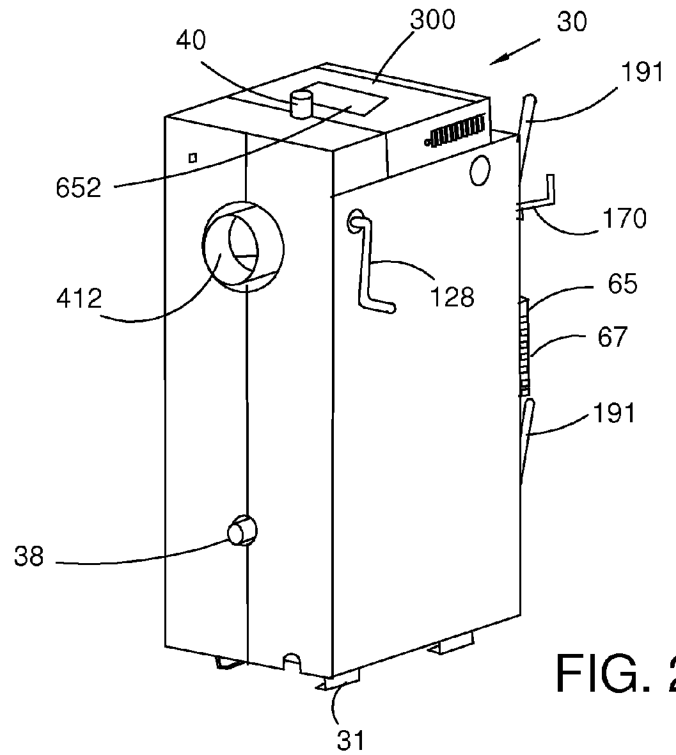
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FIG. 26

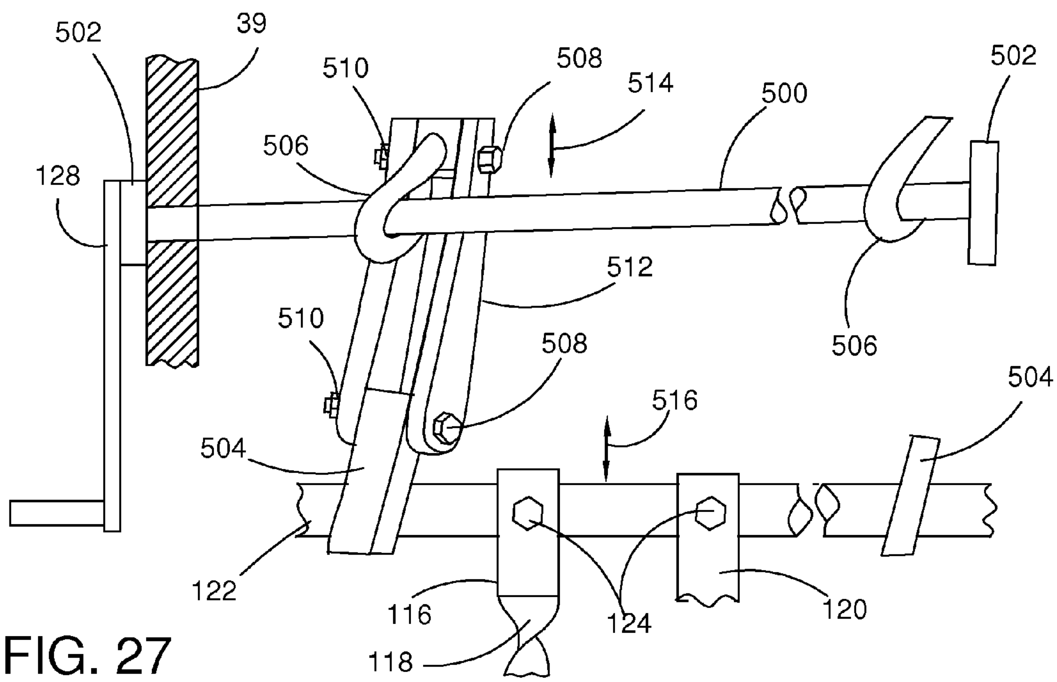
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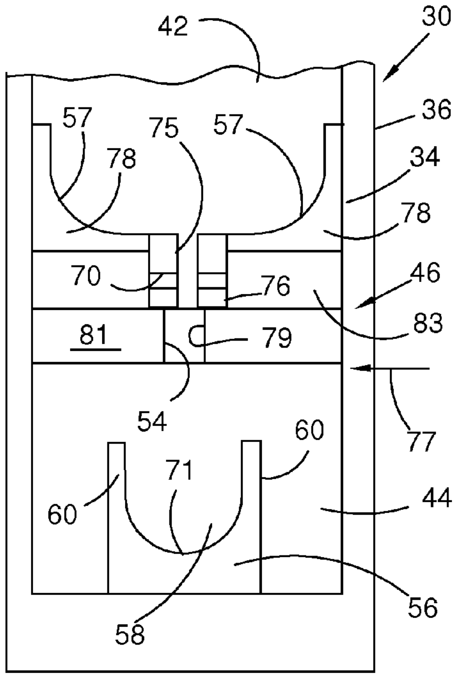
FIG. 27



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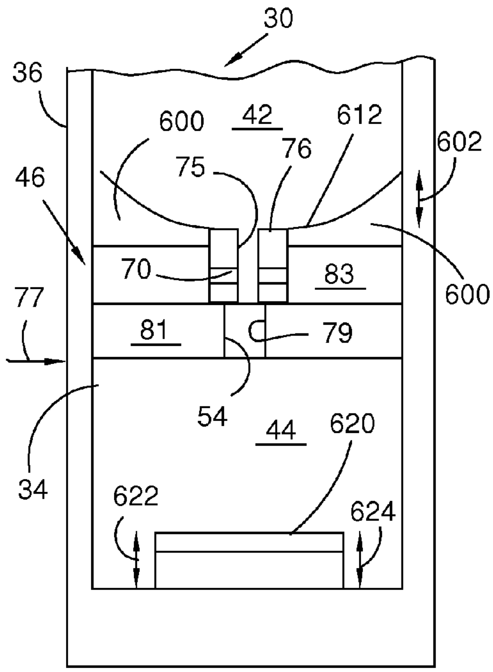


FIG. 29

FIG. 30

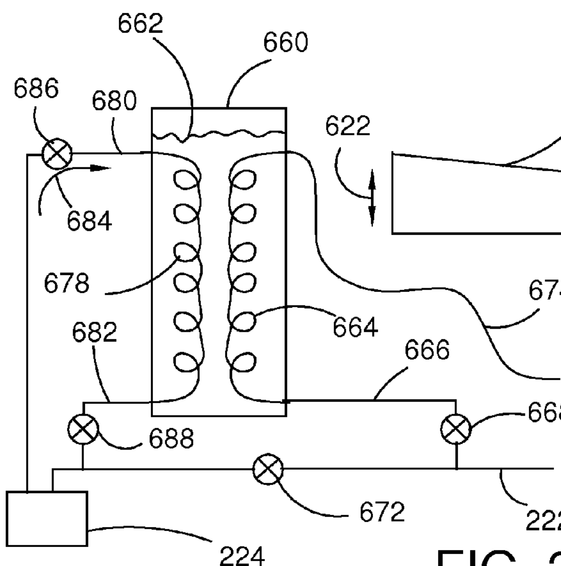
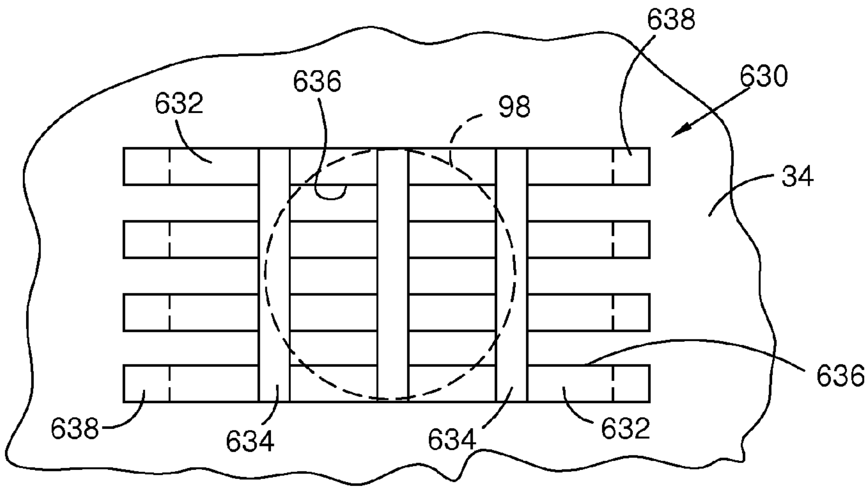


FIG. 34



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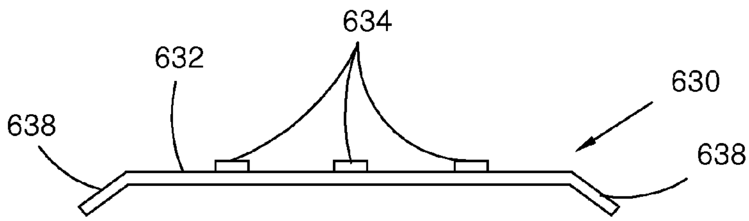

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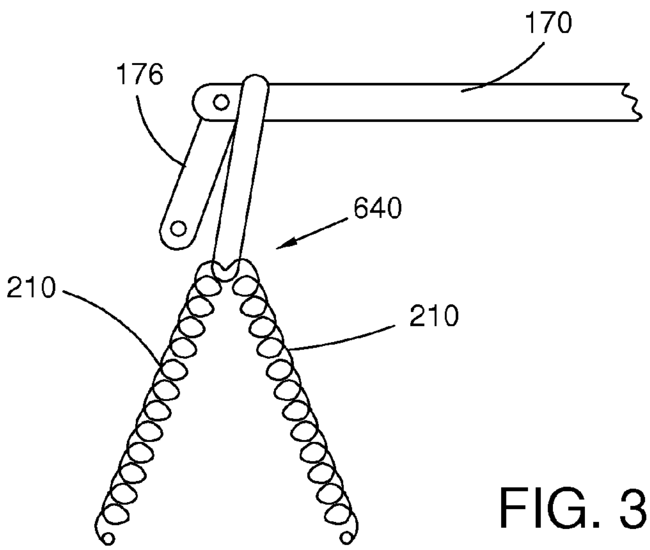

FIG. 33

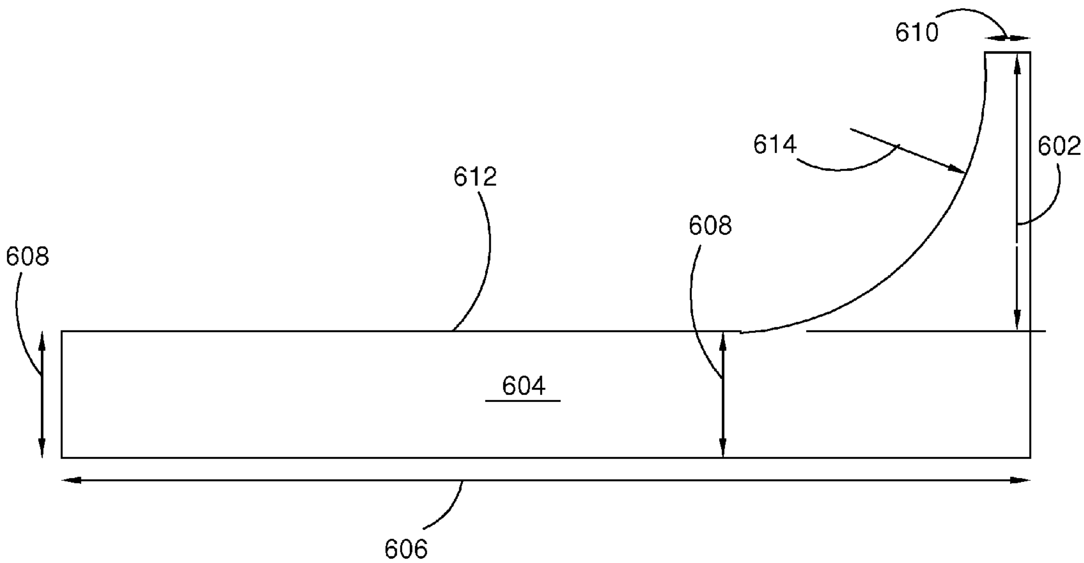

FIG. 35

HIGH EFFICIENCY WOOD OR BIOMASS BOILER

The priority of U.S. provisional application Ser. No. 61/009,787, filed Jan. 2, 2008, which is hereby incorporated herein by reference, is hereby claimed.

The present invention relates generally to boilers. More particularly, the present invention relates to boilers of the type known as gasification boilers which burn wood or biomass or the like to provide energy which heats water.

Wood has long been used as a readily available and relatively cheap source of fuel. Traditionally, wood has been the only real alternative to electricity, oil, and gas. In conventional wood furnaces, after the initial burning of the fuel, a large amount of combustible gas is released. This unburned gas may account for as much as 50 percent of the wood fuel energy, and this amount of energy is unfortunately lost.

A high percentage of this lost energy may be captured and used in a process called gasification. In a gasification boiler, the gases and unburned particles given off when burning (with primary air) the wood or biomass, which otherwise would pass up the flue, are met in a secondary combustion chamber with a jet of superheated air, resulting in a torch-like combustion of these retained gases and particles at very high temperature, such as 1100 degrees F. or more. At lower temperatures, there is thus incomplete combustion with unburned gases and particulates vented up the stack. If the temperature remains above this very high temperature, the torch-like fire consumes generally all of the wood gases and solid materials so as to derive a greater amount of the energy content of the wood or biomass thereby providing more efficient operation, i.e., achieving an overall heating efficiency which may be almost 90 percent (translating to lower wood requirements). Such high temperature secondary stage combustion may result in almost no creosote or ash, thus burning cleanly with little risk of a chimney fire. With virtually no exhaust gases, a wood gasification boiler eases the burden on the environment and greenhouse emissions.

As used herein and in the claims, the term "gasification boiler" is defined as a boiler which utilizes a forced draft air supply (which is meant to include air suction) at each of two or more stages of fuel combustion wherein gases or other fuel particles remaining after a first stage of combustion are burned in a second stage of combustion at a temperature in excess of about 1100 degrees F. to more completely burn the fuel.

Patents which may be of interest to gasification boilers include U.S. Pat. Nos. 4,513,671, 4,531,464, 4,549,526, 4,598,649, 4,635,899, 5,289,787, 5,323,716, 5,338,144, 5,338,918, 5,353,719, 5,361,709, 5,388,535, 5,417,170, 5,420,394, 5,428,205, 5,501,159, 5,586,855, 6,050,204, 6,055,916, 6,176,188, and 6718889, and all of which are incorporated herein by reference. See, relative to gasification or other non-gasification boilers, also the websites of www.alternateheatingsystems.com of Alternate Heating Systems Inc. of Harrisonville, Pa., www.woodboilers.com of Tarm USA Inc. of Lyme, N.H., www.dectra.net of Garn of Minnesota, www.centralboiler.com of Central Boiler, Inc., www.greenwoodfurnace.com, www.rohor.com, and www.eko-vimar.com.pl of Eko-Vimar Orlanski of Poland. Other patents relating to gasification include U.S. Pat. Nos. 4,287,838, 4,388,082, 4,394,132, 4,498,909, 4,601,730, 5,226,927, 5,399,323, 5,551,958, 5,803,936, 6,024,932, 6,802,974, 6,968,678, 7,144,558, and 7,214,252 all of which are also incorporated herein by reference. See also T. Nussbaumer, "Combustion and Co-combustion of Biomass: Fundamentals, Technologies, and Primary measures for Emission Reduction," 17 *Energy & Fuels* 1510-1521, 2003.

Additional patents/published applications which may be of interest to the present invention include U.S. Pat. Nos./published applications U.S. Pat. Nos. 4,444,127; 7,228,806; 2008/0041357; U.S. Pat. No. 7,241,322; 2005/0109603; 2006/0196398; 2007/0187223; U.S. Pat. Nos. 4,028,193; 4,549,526; 2,374,611; 4,917,772; 4,406,619; 1,943,213; 4,280,476; 2,352,057; 25,579; 1,527,153; 1,652,713; 1,821,204; 1,636,537; 2,443,910; 2,444,402; 4,313,418; 4,337,753; 4,494,525; 4,694,817; 6,067,979; 4,047,515; 5,920,168; and 4,226,195, all of which are incorporated herein by reference.

U.S. Pat. No. 4,635,899 discusses a Eshland Enterprises, Inc. gasification boiler as follows:

> Another prior art furnace for burning waste product particle fuel is manufactured by Eshland Enterprises, Inc. of Greencastle, Pa. under the trademark "Wood Gun". Generally referred to as a wood gasification boiler, it has an insulated housing in which an upper, primary particle fuel retention and combustion chamber and a lower, secondary or afterburning combustion chamber are formed by refractory materials. A series of generally vertically extending passageways interconnect the bottom of the upper chamber with the top of the lower chamber. A quantity of waste particle fuel delivered into the upper chamber of the boiler through a fuel inlet in the top of the housing falls toward the bottom of the upper chamber and forms into a pile of fuel particles. The pile of particle fuel is ignited and burns from the bottom adjacent the location of the passageways. Periodically, the pile is replenished by delivery of additional particle fuel through the top fuel inlet of the housing.
>
> Combustible gases generated as by-products from the burning of the particle fuel in the upper, primary chamber, along with air introduced into the upper portion of the primary chamber above the pile of fuel, are drawn downward through the passageways into the lower, secondary chamber by a draft inducing fan which creates a negative pressure drop in the lower chamber relative to the upper chamber. A suitable heat recovery unit is connected to the lower combustion chamber for capturing much of the heat produced by burning the combustible gases therein.

Alternate Heating Systems Inc. manufactures gasification boilers (like the above-described Eshland Enterprises boiler) which have a water jacket between inner and outer walls for transferring heat from the firebox to water for use of the heated water. The outer wall is composed of hot rolled ¼ inch A36 (ASME standard) steel boiler plate, and the inner wall is composed of ¼ inch stainless steel, and the inner and outer walls are connected by hot rolled steel stays welded thereto. Stainless steel undesirably cannot handle the temperature rise and fall as well as A36 steel boiler plate, and creosote (the secretion of moisture and unburned gases in a boiler) attacks stainless steel more than A36 steel boiler plate. When in combination with steel plate, over time stainless steel may undesirably create stress cracks and shorten the life of the boiler.

Greenwood, on its website, states that most wood burning furnaces and wood boilers on the market are unable to sustain a temperature of 1100 degrees F. or higher, that those typical furnaces/boilers are built with a firebox of steel surrounded by a jacket of water, that the water jacket serves to transfer heat from the firebox to the home heating system and to cool the steel firebox and keep it from melting, and that by keeping the firebox cool, the water jacket also cools the fire and prevents it from burning at the temperatures needed for complete combustion.

Greenwood says that the firebox of its hydronic wood furnace is made of super-duty ceramic refractory, cast four to six inches thick, and surrounded by layers of insulation designed to keep the heat in. A natural draft system pulls air into the furnace which fans the flames and creates a roaring fire with sustained temperatures of 1800 to 2000 degrees F. Heat from the fire is captured by a water tube heat exchanger located above the firebox in the path of escaping superheated gases. The furnace extracts heat from these escaping gases, not the fire below. Water thermostats control the operation of the furnace by monitoring the temperature of the heat transfer fluid and regulating a damper on the air intake manifold. At the desired temperature in the house, the damper closes, shutting off the flow of fresh air and extinguishing the fire. When more heat is needed, the damper opens and the furnace refires. Heat stored in the refractory walls of the firebox is said to support automatic re-firing for up to 24 hours. Although the superheating may result in some gasification, this Greenwood boiler is not considered to be a gasification boiler (see the above definition of "gasification boiler") because it utilizes a single stage and a natural draft.

Central Boiler has a non-gasification boiler which is claimed to utilize heavy gauge carbon steel or titanium enhanced stainless steel and urethane insulation and utilizes an insulated cast iron door. A baffle is said to trap heat and gases for complete combustion.

The Tarm gasification boiler is said to utilize a firebox with two distinct chambers. In the primary chamber (firebox) the wood charge is ignited. The burning occurs at the bottom of the firebox and the heat from the fire bakes the wood above releasing the wood gas from the fuel. A combustion draft fan then blows these gases through the live coals and into a superheated ceramic tunnel where secondary air is injected to complete the burning process with a 2000 degree flame. Tarm claims that this boiler burns so clean and hot that virtually no visible smoke comes out of the chimney.

Eko-Vimar Orlanski (Eko) markets what it calls a wood gasification boiler which has upper and lower combustion chambers with access doors and supplied with air by a fan. See Eko-Vimar Orlanski, Operating Manual for "Wood Gasification Boiler at 18-80 kW," obtained from the above Eko-Vimar web site in 2007. To control wood quantity, it is recommended by Eko-Vimar Orlanski (page 15 of the above Eko-Vimar Operating Manual) that the boiler be switched off, the chimney flap opened, the upper door opened and the upper chamber loaded as necessary, and the door then closed, the chimney flap closed, and the boiler switched on. To avoid gasification chamber cooling if returning water is too cool, a mixing valve, which mixes hot water with return water, is installed at the boiler's outlet. A regulator is said to modulate the fan's operating, depending on an indicator's indication of the boiler's temperature, and, if a pump is connected to the regulator, it is turned off until the boiler reaches a certain temperature, then stops below that temperature, then again activates when that temperature is again reached. A microprocessor temperature regulator for central heating boiler is designed to control air blow in the boiler and to actuate a circulating pump in central heating system.

The Eko boiler as well as other gasification boilers have turbulators to create resistance to flue gas flow in the lower chamber to effect more efficient burning.

The Eko boiler water jacket walls are composed of 4 mm (0.156 inch) steel plate which undesirably wears out rapidly, reducing the boiler life. The water jacket thereof has a heat exchanger therein, and the water jacket capacity is so small that a water storage tank is required.

The Eko boiler doors are thin and light and have refractory material therein. It is believed that the lower door might have a heat deflector plate to the inside of the refractory material. It is believed that the Eko doors have no insulation between the refractory material and the door outer skin. Eko doors have 18 gage sheet metal to the outside of the door skin with an air gap between the skin and the sheet metal to protect people touching the doors.

The Eko boiler has a pipe built coil in the top of its water jacket which runs fresh water through a cool-down unit in the event of over-heating. Such an over-heat device is considered to be possibly dangerous at the elevated temperature due to thermal shock from cold water hitting and mixing with the boiling water, and the problems that could result include broken pipes, thermal shock to the water jacket, and lowering of the boiler life, if not destroying the boiler.

It is an object of the present invention to provide a durable and rugged and heat retaining and efficient gasification boiler.

It is a further object of the present invention to heat the water evenly throughout the water jacket for less thermal shock and longer boiler life and so that the boiler can come up to temperature faster for greater efficiency.

It is yet another object of the present invention to protect the user from a pressurized wood loading chamber when opening the door to the chamber to load more wood.

The above and other objects, features, and advantages of the present invention will be apparent in the following detailed description of the preferred embodiment thereof when read in conjunction with the appended drawings wherein the same reference numerals denote the same or similar parts throughout the several views.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partly sectional diagrammic view of a boiler which embodies the present invention and illustrating the boiler in use.

FIG. **2** is a partial perspective view thereof, partly sectional, illustrating the upper chamber refractory therefor.

FIG. **3** is a front elevation view thereof.

FIG. **4** is a sectional view thereof, less the refractory, taken along lines **4-4** of FIG. **3**.

FIG. **5** is an upper or plan view thereof.

FIG. **6** is a sectional view thereof, less the refractory, taken along lines **6-6** of FIG. **5**.

FIG. **7** is a diagrammic plan view of the upper chamber refractory and associated air passages.

FIG. **8** is a perspective view of a refractory block for the upper chamber refractory.

FIG. **9** is a plan view of a refractory nozzle member for the upper chamber refractory.

FIG. **10** is a side view of the nozzle member.

FIG. **11** is the other side view of the nozzle member.

FIG. **12** is an end view of the nozzle member.

FIG. **13** is a perspective view of a refractory block for the lower chamber.

FIG. **14** is a perspective view of the boiler illustrating the upper and lower chamber doors in closed positions.

FIG. **15** is an enlarged partial view of the upper door opening mechanism.

FIG. **16** is a perspective view of the boiler with outer skins removed to illustrate the gas exhaust mechanism.

FIG. **17** is an enlarged partial view of the gas exhaust mechanism.

FIG. **18** is an enlarged perspective view of a tube bundle of the gas exhaust mechanism.

FIG. **19** is a view similar to that of FIG. **14** illustrating the upper and lower chamber doors partially open.

FIG. **20** is a view similar to that of FIG. **15** illustrating the upper chamber door partially open.

FIG. **21** is a perspective view of the upper chamber door before loaded with refractory, the lower chamber door being similar thereto.

FIG. **22** is a plan or inside elevation view of the door.

FIG. **23** is a sectional view thereof taken along lines **23-23** of FIG. **22** and showing the door loaded with refractory.

FIG. **24** is a sectional view thereof taken along lines **24-24** of FIG. **22** and showing the door loaded with refractory.

FIG. **25** is a schematic partially sectional view of the water flow path and temperature control for the boiler.

FIG. **26** is a perspective view of the boiler showing the rear, left side and top thereof.

FIG. **27** is a generally diagrammatic view illustrating the connection of a crank to the tube bundle of FIG. **18** for raising and lowering thereof.

FIG. **28** is a partial schematic elevation view of the boiler illustrating the upper chamber refractory and the lower chamber refractory block.

FIG. **29** is a view similar to that of FIG. **28** illustrating the boiler with an alternative embodiment of the upper chamber refractory and an alternative embodiment of the lower chamber refractory block.

FIG. **30** is a side view (rear to forward, as placed in the boiler) of the refractory block of FIG. **29**.

FIG. **31** is a partial view of the inner rear wall of the boiler and illustrating a flue guard.

FIG. **32** is a lower edge view of the flue guard.

FIG. **33** is a partial view of the boiler illustrating an alternative embodiment of the spring mechanism illustrated in FIG. **16**.

FIG. **34** is a schematic view of a thermal storage tank incorporated into the water outlet and inlet of the boiler.

FIG. **35** is an enlarged side view of an alternative embodiment of the upper chamber refractory of FIG. **29**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring to FIG. **1**, there is illustrated generally at **30** a gasification boiler having a housing or casing **32** (on suitable supports **31**) having inner and outer walls **34** and **36** suitably durably connected (as, for example, by welding) by a suitable number of support members or stays **33** (which may be, for example, ⅝ inch diameter steel rod) and between which is contained water (or other suitable fluid), illustrated at **51**, to be heated, as described in greater detail hereinafter, to a temperature of, for example, about 170 degrees F. for use by the user in heating his or her home, supplying hot water, and other purposes as desired. These double walls or water jacket **34** and **36** define a floor **29**, forward (between upper and lower doors **48** and **50** respectively) and rear walls **35** and **37** respectively, right and left side walls **39** and **41** respectively (FIG. **3**), and an upper wall or ceiling **43**. The distance between the inner and outer walls **34** and **36** may vary and may be, for example, in the range of about 1½ to 3 inches, providing a high volume water jacket, i.e., for example, a water capacity of 28 gallons for a 100,000 btu unit up to a water capacity of 80 gallons for a 300,000 btu unit, for faster heat-up and greater output. The water inlet (return line) and outlet piping are illustrated at **38** and **40** respectively. The double wall housing or casing can be constructed using principles well known to those of ordinary skill in the art to which the present invention pertains.

The boiler has an upper chamber, illustrated at **42**, and a lower chamber, illustrated at **44**, separated by a refractory wall **46** which is also known herein as the upper chamber refractory. Upper and lower doors **48** and **50** provide access to the upper and lower chambers **42** and **44** respectively (which define the firebox). The front-opening lower door **50** provides easy occasional maintenance by providing easy access for occasional cleaning of any ash from the secondary chamber. Sheet metal skins, illustrated at **49**, are installed about the boiler in accordance with principles commonly known to those of ordinary skill in the art to which the present invention pertains, the panel flange **410** provided to stabilize left and right back skin panels, and water jacket standoffs, illustrated at **416** in FIG. **6**, welded or otherwise suitably attached to the outer water jacket wall **36**, for attachment of the skins **49** with sheet metal screws or other suitable fasteners.

The refractory wall **46** is shown to have a central opening, illustrated at **54**, which may be, for example, rectangular in shape, extending vertically entirely through the refractory wall **46** thus providing flow communication between the upper and lower chambers **42** and **44** respectively. The refractory wall **46** is also shown to have a curved wall portion, illustrated at **57**, sloping upwardly from the central opening **54** to the left side wall **39** of the housing **32** and has a similar curved sloping wall portion **57** sloping upwardly from the central opening **54** to the right side wall **41** of the housing **32**. A generally U-shaped refractory member **56** (see FIGS. **13** and **28**), a portion of one of its walls torn away in FIG. **1** for purposes of clarity of illustration, having a horizontal open end passage, illustrated at **58**, between its vertical walls **60**, is received on the floor **29** with one end adjacent or against the rear wall **37** thereby to block passage of combustion gases through its open rear end.

During operation of the boiler **30**, the upper chamber **42**, as discussed hereinafter, is pressurized since the only exit for combustion gases is downwardly through the narrow opening **54**. A damper or blast plate **55** (FIG. **16**) is provided in the upper portion of the rear wall **37**, as hereinafter discussed, to relieve the pressure when the upper chamber door is opened to, for example, load additional wood **62**. Accordingly, in accordance with the present invention, the refractory structure **46** extends entirely across (i.e., over entirely 360 degrees horizontally) and sealingly engages the inner casing **34** in a manner to seal the upper combustion chamber **42** from the lower combustion chamber **44** so that the upper combustion chamber **42** can be made substantially air tight (it being understood that the "sealing" and "air tightness" is with the exception of the passage **54** to the lower combustion chamber **44** for the pressurized expulsion of combustion gases and particulates therethrough). Thus, the upper combustion chamber **42** is sealed to provide air tightness (at least substantially) by the refractory structure **46** and by the closing of the damper **55** and upper refractory chamber door **48**, with the result that the combustion products are forced by the forced draft through the narrow central opening **54** at high speed. It is also to be understood that the opening **54** passes through the nozzle member **76** and the underlying refractory material, as discussed hereinafter.

Operation of the boiler starts (with the damper **55** closed) with loading the upper chamber **42** with fuel in the form of logs **62** or other suitable wood or biomass, the logs being laid on top of the refractory wall **46**, and having water **51** circulating in the water space **52** between the inner and outer walls **34** and **36** respectively. With the doors **48** and **50** closed, primary air is supplied by a forced draft fan **64** (within housing **65** having air inlet openings **73**) through vertical conduits **66** (FIGS. **4** and **7** as well as FIG. **1**) and is discharged at conduit outlets **68** in the upper part of the upper chamber **42**. Alternatively, a suction blower could be used to effect a draft or air flow by suction. The primary air supplies oxygen for burning the wood **62** in the upper chamber **42**. The burning of the wood **62** is initiated in any suitable manner such as manually, for example, by the use of newspapers and the application of a lighted match thereto. The chamber **42** is suitably constructed to be, with the damper **55** and upper chamber door **48** closed and with the exception of the central opening **54**, a closed chamber, allowing escape of the combustion products, illustrated at **68**, only downwardly through the narrow central opening or nozzle **54** at high speed. Heat from the primary combustion in the upper chamber **42** is given up to the inner wall **34** along the upper chamber **42** to heat the water **51** between the inner and outer walls **34** and **36** respectively surrounding the upper chamber **42**.

As the unburned gases and other combustion products flow downwardly through the central opening **54**, they are supplied by the forced draft fan **64** with secondary air via tubes **72** to outlets, illustrated at **70**, in the central opening **54**, as more specifically discussed hereinafter. Once the refractory **46** reaches a temperature in excess of about 1100 degrees F., for example, in the 1400 to 1500 degrees F. range, it ignites the oxygen in the secondary air along with the unburned gases/solids from the burning of the wood **62** thereby "gasifying" the combustion products to efficiently extract a very high percentage of the wood heat content. The resulting gasified material, illustrated at **74**, flows downwardly at high speed between the walls **60** and impinging on the floor **71** of the refractory member **56**. The refractory member **56** is U-shaped (or otherwise suitably shaped, as discussed hereinafter with respect to FIGS. **29** and **30**) to channel the flame and heat to stay awhile in the lower chamber **44**, burning more unburned gases (the hotter it gets, the more unburned gases/particulate is burned) for even cleaner and more combustion efficient burning—so that very little particulate or gases remain to be released from the boiler **30**. The heat/gases flow forwardly (toward the front of the boiler) from the passage **58** and upwardly, giving up heat to the water **51** in the lower chamber **44** all along the surfaces of the inner wall **34**, then whatever waste/gases/particulate remains is released from the boiler **30** as will be discussed in greater detail hereinafter.

It is now considered that the optimum percentage of moisture for wood gasification is about 15% to 23%. A long burn cycle of up to 8 to 10 hours translates to less hassle and more comfort.

Referring to FIGS. **7**, **8** to **12**, and **28**, the upper chamber refractory wall **46** includes a centrally disposed refractory nozzle member or block **76** (or more) containing an opening **75** which is part of the opening or nozzle **54** extending vertically entirely through the refractory wall **46**. The nozzle block **76** is surrounded by four (or other suitable number) of refractory blocks **78** each having a bottom wall **80**, a short inner wall **82** extending vertically upwardly from the inner end of the bottom wall **80**, a vertical side wall **84**, a short upper wall **86** extending horizontally inwardly from the upper end of the bottom wall, and a curvilinear wall **88** sloping upwardly and outwardly from the upper end of wall **82** to the inner end of wall **86** thereby defining the sloping wall portions **56** and **57** which may be said to form a forwardly and rearwardly extending trough upon which the wood **62** is placed. Refractory material, illustrated at **90**, is molded in situ in and among refractory blocks **76** and **78** and extending sealingly to the inner wall **34** on all sides to define the refractory wall **46** sealingly separating (with the exception of the nozzle **54** for passage downwardly of primary combustion products) the upper and lower chambers **42** and **44** respectively and defining the aforementioned trough. The refractory wall **46** is formed in situ as below described.

The secondary air tubes **72** are welded or otherwise suitably attached to the inner wall **34** at the rear of the boiler **30**, and they extend through the inner and outer walls **34** and **36** at the front of the boiler **30** where they are suitably connected for flow communication with the blower **64** in accordance with principles commonly known to those of ordinary skill in the art to which the present invention pertains.

A section of plywood (not shown) is supported at the desired level, illustrated at **77** in FIG. **28**, of the under surface of the refractory wall **46**. The plywood is provided with a central depression therein in which is placed a plastic insert to provide the downward gas passage portion, illustrated at **79**, from the bottom of the nozzle member **76** into the lower chamber **44** when the refractory mortar material is laid and cured. A layer **81** of refractory mortar (for example, about 3 inches thick) is poured or laid onto the plywood and around the plastic insert to just under the secondary air tubes **72** and allowed to cure (for example, about 3 days), then the plywood and insert removed, leaving the vertical passage **79** for alignment of the nozzle **75** therewith to complete the passage **54** entirely through the refractory structure **46**. To obtain a good bond with the inner wall **34** all the way around, rebar-like members may be welded to the inner wall **34** to extend into the mortar or other suitable means may be employed in accordance with principles commonly known to those of ordinary skill in the art to which the present invention pertains.

After the bottom refractory layer **81** is cured, the nozzle member **76** is placed in position with the nozzle **75** aligned with the passage **79** formed in the bottom refractory layer **81**, and plastic tubes positioned each with one end inserted in a secondary air inlet aperture or passage **70** in the nozzle block **76** and the other end inserted in a corresponding aperture, illustrated at **92**, in the wall of a corresponding tube **72** to form an air passage, illustrated at **94**, therebetween when a second layer of refractory, illustrated at **83**, is poured or laid and cured. The second layer **83** of refractory mortar (for example, about 3 inches thick) is then poured onto the cured first layer **81** and around the nozzle block **76** and covering the tubes **72** and inserts for passages **94** up to a level about one inch below the top of the nozzle block **76** and allowed to cure (for example, about 3 days), and this layer **83** may also be suitably bonded/attached to the boiler inner wall **34** similarly as described above for the first layer **81**. The plastic tube inserts for passages **94** burn out when the boiler **30** is first fired.

The L-shaped refractory members **78** are then placed in position and a third layer **85** (FIG. **7**) of refractory mortar is poured or laid up to the top of the nozzle block **76** and additional refractory mortar troweled in to form the desired final form of the upper surface of the refractory wall **46** and allowed to cure (for example, about 3 days). If needed due to space limitations, the L-shaped blocks **78** may be suitably notched to fit with or accommodate the nozzle block **76**. Again, as needed or desired, this layer **85** may also be suitably bonded/attached to the boiler inner wall **34** similarly as described above for the first layer.

Depending on the boiler size and requirements, the refractory wall **46** may contain more than one nozzle block **76**, and a nozzle block may contain more than one air inlet passage **70** on each side. Preferably, the air inlet passages **70** are offset, as seen in FIG. **9**, to reduce interference of air passage with each other and provide a more even flow of secondary air into the nozzle.

The refractory blocks **56**, **76**, and **78** and the refractory material **90** may (but need not) have the same composition, which is as described below.

In accordance with the present invention, the refractory material (**56**, **76**, **78**, and **90**) is preferably of a type which retains heat to a temperature in excess of about 2100 degrees F. in order to achieve the desired efficient secondary combustion. Moreover, the refractory material preferably also retains heat for a long time (several hours, for example, 12 hours or more) so that, for example, one can cease using the boiler **30** in the morning and the refractory material will still be hot enough at night to self-ignite when some wood **62** is loaded to re-start the boiler **30**. The refractory material is also desirably one that doesn't break down in water and disintegrate, doesn't have to be replaced often, and has a high alumina content for insulating capability, strength, and heat retention. As used herein and in the claims, the term "refractory" refers to a material, whether lining or otherwise contained within the firebox space of a furnace, which is resistant to the heat encountered therein. A suitable refractory material (**56**, **76**, **78**, and **90**) has been found to be one known as Matripump 60 sold by Matrix Refractories, a division of Allied Mineral Products, Inc. of Columbus, Ohio (www.alliedmatrix.com and www.alliedmineral.com). Such a refractory material is claimed to have as major components 62.0 percent aluminum oxide (alumina), 32.8 percent silicon dioxide, 2.0 percent calcium oxide, and 1.0 percent iron oxide, is said to contain aluminum oxide, calcium aluminate cement, aluminum silicates, and silica, is indicated to have a maximum use temperature of 3100 degrees F., is indicated to have the further benefits of outstanding thermal shock properties and excellent abrasion resistance, and tolerates a wide water range (for molding purposes) without sacrificing physical properties.

Referring to FIGS. **16** to **18**, the waste products of combustion pass from the lower chamber **44** pass through an opening, illustrated at **112** in FIGS. **6** and **16**, in the rear wall **37** and into a plenum chamber **102** containing flow-directing baffle(s) **104**. These waste products then are directed, as illustrated at **105** in FIG. **18**, from opening **112** to and pass into and flow upwardly through a bank of vertical tubes **100** which are welded or otherwise suitable connected to an upper plate **114** of the chamber **102** in flow communication therewith. After leaving the upper ends of the tubes, these waste products pass into an upper plenum chamber **96** (FIG. **4**—outer plates of the plenum chamber **96** removed in FIGS. **16** and **17** for ease of illustration). Waste products passing through the damper opening **98** when the damper **55** is open also pass into plenum chamber **96**. The waste products from the tubes **100** and from the damper opening **98** pass out of the boiler **30** through a stack or exhaust pipe, illustrated at **412**. The bank of vertical tubes **100** are received within a chamber **106** defined as between the outer **36** of the double walls and an outer wall **108**. The gases/particulate matter pass upwardly in chamber **106**, as best seen in FIG. **4**, and out exhaust pipe **412**.

In order to restrict the flow of the waste products through the tubes **100** so as to create back pressure so that the products linger longer in the lower combustion chamber **44** thereby more efficiently giving up their heat to the water **51**, in accordance with the present invention, an elongate flow restrictor or turbulator **116** is provided in each of the tubes **100** to extend along the length thereof. Each turbulator **116** is formed in the shape of a spiral blade **118** (continuing the pattern as seen at the top of FIG. **18**) the upper end of which ends in a generally flat portion **120**. The turbulators **116** may be otherwise suitably shaped to suitably restrict flow. A horizontal bar **122** is suitably connected, as by bolts **124** received in holes **126** in the bar **122** and corresponding holes in the portions **120** and secured by nuts (not shown), or otherwise suitably connects the turbulator portions **120**.

Referring to FIG. **27**, each end of the bar **122** is suitably connected to a crank **128**, as discussed hereinafter, for periodically (for example, twice daily) translating the turbulators **116** up and down for cleaning, i.e., to prevent solids build-up on the tubes **100**. The crank **128** is suitably fixedly connected to an elongate member **500** which is suitably rotatably mounted at its ends within bores of bearing members **502**. Brackets **504** are fixedly attached to opposite end portions of bar **122**, and corresponding brackets **506** are fixedly attached to rotatable member **500**. A yoke **512** (only one shown) is pivotly connected at its ends to corresponding brackets **504** and **506** respectively by suitable means such as for example, a bolt **508** and **510** received in a bushing (not shown). Thus, rotational movement of the crank **128** and the corresponding rotational movement of the rotatable member **500** effects up and down movement, illustrated at **514**, of the yokes **512** which in turn effect up and down movement, illustrated at **516**, of the turbulator bar **122** and accordingly the turbulators **116**.

A typical gasification boiler may have 4 mm (0.156 inch) boiler plate or a combination of stainless steel (for the inner water jacket wall) and boiler plate (for the outer water jacket wall). 0.156 inch boiler plate doesn't last very long (perhaps only as much as about 5 to 6 years) due to acidity eating through, and stainless steel and boiler plate steel expand and contract at different rates resulting in break-down stress-wise, as discussed more specifically hereinbefore. In order to provide the boiler **30** to be long lasting, in accordance with the present invention, the inner and outer firebox walls **34** and **36** are each composed of boiler plate (for example, A36 hot rolled steel plate) having a thickness, illustrated at **130** in FIG. **25**, of about ¼ inch (or greater), connected by welding with ⅝ inch diameter hot rolled steel stays. Seams are desirably double welded for strength and durability for excellent temperature and corrosion resistance.

In a conventional boiler, doors may have to be replaced often (perhaps about every 2 years), and substantial heat may be lost through the doors. Referring to FIGS. **21** to **24**, upper door **48** is provided with a refractory block **132** (not shown in FIGS. **21** and **22**), and lower door **50** is similarly provided with a similar refractory block, and thus the description for the door **48** will apply also to the door **50**. The refractory block **132** is provided to absorb heat so that the door **48** may be protected from the intense firebox heat and accordingly need not have to be replaced often and (especially for the lower door **50**) to provide further heat-retaining refractory for aiding in combustion.

The door **48** includes an outer skin **134** formed of, for example, 10 gauge steel plate, bent at about 90 degrees inwardly along three sides to form upper and lower flanges **136** and **138** respectively and a left side flange **140** which are welded together along their adjoining edges. The flange **140** has a centrally located aperture, illustrated at **142**, adjacent its outer edge whose purpose will be described hereinafter. A 90-degree angle iron **144** extends along the right edge of the skin **134** with one flange **146** suitably welded thereto and the other flange **148** extending inwardly from the laterally inner end thereof, as soon in FIG. **23**. The angle iron **144** is suitably hingedly connected as by hinges **150** (FIG. **3**) to the boiler front wall to allow opening and closing of the door **48**.

A plurality of, for example, 4 steel spacers or short rods or studs **152** are suitably welded to the inner surface of the skin **134** to extend inwardly therefrom and are generally evenly spaced. A flat or planar plate **154**, which may for example be a 10 or 12 gauge steel plate, is positioned to lie on the spacers **152** between the flanges **136**, **138**, **140**, and **148** and may be suitably welded thereto and is welded to the respective ends of the spacers **152**.

A pair of spaced laterally spaced centrally positioned spacers or rods or studs **162** are suitably welded to the inner surface of the plate **154** to extend normal thereto and inwardly therefrom for purposes which will be described hereinafter.

The refractory block **132** is suitably molded situ on the plate **154** (but may alternatively be pre-molded) and extends inwardly from and normal to the plate **154** for a short distance, as illustrated at **156**, then is bent to be tapered laterally inwardly at a taper, illustrated at **158**, of, for example, about 30 degrees. Along each of the edges (but spaced therefrom for reasons described hereinafter) of the plate **154** is welded or otherwise suitably attached (prior to the pouring and molding of the refractory block **132**) a suitably sized and shaped refractory holding plate **160**, which may, for example, be 10 gauge steel, which extends inwardly from and normal to the plate **154** for a short distance to engage the refractory block **132** then tapers at the angle **158** so that the four plates **160** will hold the thereafter poured and molded refractory block **132** in place.

A gasket seal **164** for suitably sealingly engaging a respective edge, illustrated at **165** in FIG. **20**, of the opening in the front wall for providing a seal when the door **48** is closed is provided in the gap between each of the refractory holding plate portions **156** and the respective one of the flanges **136**, **138**, **140**, and **148**, all of which extend inwardly beyond the plate **154** to house the gasket **164**. Alternatively, a single gasket may be provided to extend all the way around the door **48**. The gasket **164** may, for example, be a ¾ inch square section of ceramic fiber.

In order to reduce heat transfer from the refractory block **132** to the door outer skin **134** to thereby prevent the door **48** from becoming too hot to touch and to prevent or reduce the loss of heat through the skin **134**, in accordance with the present invention, suitable insulation material **166** is packed in the space between the plate **154** and the skin **134** (prior to the installation of the plate **154**). The insulation material **166** may, for example, be of a type sold by Smock & Shonthayler of Erie, Pa.

The spacers **162** are sized to have a length to extend beyond the refractory block **132**. A planar or flat heat deflector plate or heat shield **168** is welded to the inner ends of the spacers **162** to deflect heat back into the firebox. The deflector plate **168** may, for example, be ¼ inch thick steel. The deflector plate **168** and spacers **162** may, if desired, not be provided for the upper door **48** where the heat is less intense.

Referring to FIGS. **16** and **17**, a rod **170** is provided for opening the damper **55** for relieving pressure in the primary or upper chamber **42** so that the door **48** can be safely opened for loading additional wood **62** therein. The rod **170** extends horizontally between the front and rear of the boiler **30** adjacent the outer wall **36** and inside the outer skin on the left side and extends through a suitable opening, illustrated at **171** (FIG. **15**), in the forward boiler skin and is screw-fitted at its front end with a handle **172**. The rod **170** is pushed inwardly for opening the damper **55** and pulled outwardly for closing the damper **55**. The rod is slidingly held in position by a U-bolt **174** or other suitable fastener welded or otherwise suitably attached to the outer wall **36** and positioned closer to the boiler front wall **35** than to the rear wall **37**. At its rear end, the rod is suitably pivotly attached to one end of a bracket **176**. The other end of the bracket is suitably attached to one end of a laterally extending rod **178** to thereby effect rotation of the rod **178**. The other end of the rod **178** is suitably rotatably received in an aperture, illustrated at **180**, of a bracket **182** which is welded or otherwise suitably attached to the upper wall **184** of the turbulator housing and/or the rear outer wall **36**. One end of an elongate bracket **186** is welded or otherwise suitably rigidly attached to the rod **178** to extend generally vertically therefrom. The other end of the bracket **186** is suitably attached such as by a screw **188** to the circular damper **55** centrally thereof. Thus, by pushing inwardly on the rod **170**, as indicated at **190**, the bracket **176** is caused to effect rotation of the rod **178** counterclockwise to effect movement of the upper end of the bracket **186** rearwardly thereby pulling the damper **55** away from the exhaust opening **98** thereby opening the damper **55** so that pressure in the upper chamber **42** can be relieved through the damper opening **98**. By pulling forwardly on the rod **170**, the damper **55** is caused to move forwardly and sealingly close the opening **98** (by the reverse of what is described above for opening the damper **55**) so that the boiler can be suitably operated with the upper chamber **42** pressurized, the interface between the damper **55** and the opening **98** being suitably sealed in accordance with principles commonly known to those of ordinary skill in the art to which the present invention pertains.

Referring to FIGS. **15** and **20**, a handle **191** is suitably rotatably mounted to the left side door flange **140** (for each door **48** and **50**) by a suitable fastener **192** received in an aperture, illustrated at **193**, in the handle **191** and in the aperture **142** (FIG. **21**) in the door flange **140**. The door opening is formed by forwardly extending flanges **194** from the forward wall, the flanges presenting the edges **165** for sealingly engaging the gasket or gaskets **164**. The handle **191** includes a generally vertically upwardly extending handle portion **196** for application of leverage by the operator and a suitably shaped claw portion **198**. One end of a suitable generally cylindrical member **201** is welded or otherwise suitably attached to the left side flange **194**, in accordance with principles commonly known to those of ordinary skill in the art to which the present invention pertains, to receive the handle claw **198** in a manner to apply force to tightly sealingly close the door **48** (and similarly, door **50**), by rotation of the handle portion **196** counterclockwise (as viewed in FIG. **15**). By rotation of the handle portion **196** clockwise, the door **48** (and similarly, door **50**) is opened.

As previously discussed, it is considered important that the upper door **48** not be opened until the damper **55** has been opened to relieve pressure in the upper chamber **42**. Referring to FIGS. **15** and **20**, in order to avoid accidental opening of the upper door **48** while the damper **55** is closed, in accordance with the present invention, a mechanism, illustrated generally at **200**, is provided preventing the clockwise rotation of the handle **191** for opening the door **48** while the damper **55** is in a closed position with the rod **170** pulled rearwardly as seen in FIG. **15**. The mechanism **200** comprises a pair of blocks **202** and **204** welded or otherwise suitably attached to the handle portion **196** (adjacent to its point **192** of attachment to the door **48**) and rod **170** respectively in suitable positions, as seen in FIG. **15**, to engage each other when the door **48** is closed and the damper **55** closed. The rod **170** is shown to be disposed laterally outwardly of the handle **191**. The handle block **202** is welded to the handle **191** so as to extend laterally outwardly therefrom, and the rod block **204** is welded to the rod **170** so as to extend laterally inwardly therefrom such that major portions of the blocks **202** and **204** may engage each other without interference by the handle **191** or rod **170**. Block **204** has a lip **206** extending upwardly from its upper forward corner which engages or is received in a mating cut-out, illustrated at **208**, in the lower forward corner of the handle block **202**. The lower surface of the block **202** rests on or engages the upper surface of block **204** with the lip **206** acting as a stop to movement of the block **202** forwardly and thus acts as a stop to clockwise movement of the handle **191** for opening the door **48**. The rod **170** is spring-biased to retain the lip **206** in the cut-out **208** by a spring **210** (FIG. **16**) having one end suitably attached to the rod **170** at a point located between the U-bolt **174** and the bracket **176** (the spring **210** extending downwardly therefrom and its other end suitably attached to the left outer wall **36**) thereby, with the U-bolt **174** acting as a fulcrum, urging the forward end of rod **170** upwardly whereby the lip **206** is urged into engagement with the cut-out **208**.

When it is desired to open the upper door **48** for loading of additional wood **62** or otherwise, the rod handle **172** is pushed downwardly, as indicated at **212**, against the force of the spring **210**, then pushed rearwardly, as indicated at **190**, to open the damper **55**. This clears the block **204** from acting as a stop, whereby with, the pressure relieved by the opening of the damper **55**, the door **48** can now be safely opened. After the wood **62** is loaded and the door **48** closed, the damper **55** may be closed to allow the upper chamber **42** to again become pressurized for normal operation by pulling forwardly on the rod **170**, using handle **172**, until the lip **206** again engages cut-out **208** and is held therein by the bias force of spring **210**, thereby again preventing the door **48** from being opened until the operator has taken steps to remove the impediment of the mechanism **200**, which can be done by opening the damper **55** as discussed above. Other suitable mechanisms can be provided for insuring that the damper **55** is open before the door **48** is opened. Such other mechanisms are meant to come within the scope of the present invention.

Referring to FIG. **25**, as previously discussed, the water **51** to be heated is contained between double walls **34** and **36**, the inner wall **34** defining the interior of the firebox including the upper, rear, bottom, and side walls, and the wall portion between the doors **48** and **50**. The inner wall **34** efficiently affords direct heat transfer from the heat generated in the firebox directly through the inner wall **34** to the water **51**. When the water **51** is at the desired temperature for use, it is pumped, as illustrated at **225**, by a suitable pump **220** from outlet line **222** to use points, indicated at **224**, which may be primary or supplementary high volume heating and domestic hot water needs for commercial and residential applications, for example, for supply to a residential hot water heater or heating system. The water return is via a return line **226** to boiler inlet **38**.

The pump **220** is normally off until the water **51** is at the desired temperature. In accordance with the present invention, a suitable circulation pump **230**, which may be an electric or other suitable pump, is provided to internally circulate the water **51**, as illustrated at **227**, so that it is evenly heated throughout the water jacket for less thermal shock and longer life, i.e., the water is directly pumped from the water outlet **40** to the water inlet **38**. By "directly" is meant that the use points **224** are by-passed by the flow of water from the outlet **40**. Such internal circulation is also provided for more efficient operation by bringing the boiler up to temperature faster and thus better utilization of the fuel **62**, i.e., not as much fuel is needed to get up to gasification temperature.

Because the upper chamber **42** is pressurized, it is important that gasification be suitably maintained as well as the water temperature regulated. The regulator therefor is illustrated at **300** and includes a suitable controller **302** and fan controller **304**. The regulator unit **300** may utilize industrial grade touch pad control units, sold by Automation Direct Controls of Atlanta, Ga., to optimize the wood boiler's combustion efficiency. The controller **302** receives water temperature input from a temperature probe or thermocouple **306** suitably in contact with the outer wall **36** to obtain a measurement of water temperature. An LED display **308** of the water temperature may also be provided. The controller **302** is suitably programmed, utilizing principles commonly known to those of ordinary skill in the art to which the present invention pertains, to shut down the circulating pump, via line **310**, and to turn on the primary pump **220**, via line **312**, at a predetermined set point, for example, about 130 degrees F. water temperature as measured by thermocouple **306**.

In accordance with the present invention, the fan controller **304** is suitably programmed, using principles commonly known to those of ordinary skill in the art to which the present invention pertains, to control water temperature to the predetermined set point, illustrated at **320**, of, for example, about 170 degrees F., by signaling via line **322** an AC (or other suitable) motor **324** powering the blower **64** to operate alternately at a high and a low speed, for example, to operate at a 100 percent output speed to increase temperature to the set point temperature, and to operate at a 50 percent output speed after the set point temperature has been reached to allow some drop in temperature below the set point temperature and thereafter again operating at the 100 percent output speed to again increase temperature to the set point temperature, etc., etc., thereby effecting an oscillating of the temperature near the set point temperature as is well known in the art to which the present invention pertains. By operating the blower **64** at the lower speed to allow the water temperature to decrease, the combustion process is continued during this period of time with the flame under control, without the necessity disadvantageously of having to periodically cease the combustion process. It should of course be understood that the blower motor **324** may be operated at various other higher and lower speed combinations as suitable to achieve the desired water temperature control.

A suitable aquastat or water temperature sensor **554** is suitably connected in the water flow line (as shown in the water outlet **40**) using a suitable immersion well or as otherwise suitable and is suitably connected via line **552** to the blower motor **324** to turn off the blower **64** at a suitably programmed overheat set point of, for example, about 220 degrees F. water temperature. At the same set point temperature, the controller **302** is suitably programmed to effect the sounding of an alarm **556** and to turn off the primary pump **220** and turn on the circulating pump **230** (via lines **312** and **310** respectively) to dissipate heat and allow the water temperature to drop.

A line **562** is in parallel with the water usage units **224**, and a suitable self-contained (i.e., not connected to an outside source of electrical power) valve **560** is installed in line **562** to sense water temperature and to automatically open to divert outlet water to a means for dissipating heat, as hereinafter described, at the above set point of, for example, about 220 degrees F. water temperature, this valve thus operating even in the event of power failure of outage. One means for dissipating heat is hand operated valve **564** downstream of valve **560** which releases the hot water as illustrated at **566**, and cold or cooler make-up water from, for example, a city's water supply **568**, is supplied to the system via valve **572** and line **570**, as illustrated at **574**. An alternative means of dissipating heat is by perculation through a water tank **576** in line **562** wherein the tank is installed at a location vertically higher than the boiler and the line is coiled to provide a submersible coil **578** inside the tank to suitably exchange heat in the outlet water to the water in the tank **576** to quickly dissipate heat. The tank **576** may have a capacity of, for example, 50 to 500 gallons, depending on the size of the boiler. If desired, a suitable hand operated valve, which should remain normally open if installed, may be installed in line **562**, to be closed only when valve **564** is opened, and other valves may be located in the lines as suitable or desired. Suitable super vents **580** are suitably provided in highest points in the water lines to vent air. In line **570** a suitable shock-absorbing bladder **582** is installed to keep the water lines at suitably an even pressure of, for example, 20 psig. While one water pump **220** is shown for pumping the water through the load **224**, it should be understood that it may be otherwise suitably positioned or other suitable pumps may be suitably installed as needed to assist and maintain suitable water flow. For example, pump **220** may alternatively be positioned at the water inlet **38**.

In the event that the over-temperature device described above for turning off the blower at the overheat set point fails, a redundant control is provided for use at a higher temperature, as follows. The controller **302** is also suitably programmed to shut off system power, via line **550** to power supply **558**, to thereby shut down the entire system at a water temperature of, for example, about 225 degrees F., including redundantly shutting off the blower **64**, eliminating the flow of air/oxygen to the fire box, which will then redundantly allow the fire therein to smolder.

Illustrated at **590** is a suitable safety or pop-off valve which is installed through the outer water jacket wall **36** in flow communication with the water therein and which is set to open at a pressure of about 30 psig (or other suitable pressure) to release pressure/steam from the water jacket, as illustrated at **592**, in the event of failure of the safety shut-off systems at the lower temperatures (at 220 and 225 degrees F.) discussed above. The valve **590** may, for example, be one identified as model number 335M1 sold by Watts Regulator Company of North Andover, Mass.

Referring to FIG. **29**, there is illustrated at **600** refractory blocks which have an alternative shape to the refractory blocks **78** of FIG. **28**. These refractory blocks **600** are illustrated to have a reduced height, illustrated at **602**, above the floor **612** to allow a smoother, more even, bed of coals to form and to eliminate "bridging" of the wood **62** in the upper combustion chamber **42**. "Bridging" occurs when wood **62** in the bottom of the upper combustion chamber **42** burns up but wood **62** in the upper portion thereof that does not fall "bridges" together and may as a result not burn.

Referring to FIG. **35**, there is illustrated at **604** another example of a refractory block suitable for prevention of such "bridging." Refractory block **604** has a width, illustrated at **606**, which is roughly equal to the distance between the nozzle block **76** and the boiler wall **34**, for example, about 7.75 inches, it being understood that refractory mortar may be laid and cured between the refractory block **604** and the boiler wall **34**. This width **606** will vary depending on the size (width) of the boiler **30**. Its height, illustrated at **608**, at the nozzle block **76** may be, for example, about 1 inch, and this height remains constant over a distance which will also vary according to boiler size and is shown in the example of FIG. **35** to remain constant over approximately ⅔ of the width **606**. Its thickness, illustrated at **610**, at its highest point adjacent the boiler wall **34** is, for example, about 0.375 inch. The block upper surface or floor, illustrated at **612**, upon which wood **62** is placed for burning, is curved adjacent the boiler wall **34** by a radius, illustrated at **624**, of, for example, about 2 inches. Height **602** adjacent the boiler wall **34** of the block above the floor **612** is, for example, about 2.25 inches (with the overall block height being about 3.25 inches). In order to prevent "bridging," it is important that this height **602** (over which the block extends above the floor **612**) not be too high. Thus, no matter what the boiler size, it is important, for the prevention of "bridging," that the height **602** be less than about 2¼ inches. It should of course be understood that the refractory block **604** may be otherwise suitably sized and shaped, such as illustrated in FIG. **29**.

Referring to FIGS. **29** and **30**, there is shown at **620** a lower combustion chamber refractory block having an alternative shape. In order to provide greater ease of cleaning and servicing of the boiler **30** with no change in emissions, the refractory block **620** is flat and tapered from rear to front (towards the door **50**) of the boiler **30**. For example, the height, illustrated at **622**, of the refractory block **620** is about 2 inches, and it tapers to a height, illustrated at **624**, at the front which is about 1 inch. The forward downward slope of the refractory block **620** is believed to cause the particulates to be deflected forwardly before they are deflected rearwardly for more resonance time for scrubbing emissions (carbon monoxide, etc.). In addition, ash is forced more forwardly to thereby reduce particulates being forced up the stack.

It has been discovered that wood may sometimes be thrown up into an unguarded flue (damper opening **98**) thus rendering the flue damper or blast gate **55** inoperative. Referring to FIGS. **31** and **32**, a flue guard **630** in the form of a grate or grid is welded (or otherwise suitably attached) to the inner surface or fire side of boiler wall **34** to protectively cover the damper opening **98**. As seen in FIGS. **31** and **32**, the grid **630** includes a plurality (such as, for example, four) of spaced horizontal steel strips **632** and a plurality (such as, for example, three) of spaced vertical steel strips **634** which cross the horizontal strips **632** and are welded (or otherwise suitably attached) thereto, thereby leaving a plurality of flue passages, illustrated at **636**. The end portions **638** of the horizontal strips are uniformly bent so as to space the grid **630** from the damper opening **98**, and it is these bent portions **638** that are welded (at their ends) to the boiler wall **34**. The grid **630** may of course be otherwise suitably sized and shaped. For example, the vertical strips **634** could alternatively be welded to the boiler wall **34**.

Referring to FIG. **33**, there is illustrated an alternative embodiment of the spring biasing mechanism for retaining the lip **206** in the cut-out **208** (FIG. **15**) so that the upper door **48** is not opened until the damper **55** has been opened to relieve pressure in the upper combustion chamber **42**. The spring mechanism, illustrated generally at **640**, is positioned adjacent the rear end of the rod (adjacent the link **176**) and is provided with two springs **210** attached to bracket **642**, which is suitably attached to the rod **170**, and which are offset as they extend downwardly (one spring **210** inclined forwardly and the other inclined rearwardly) in order to provide for both a positive opening and a positive closing of the damper **55** while also retaining the lip **206** in the cut-out **208** (FIG. **15**) so that the upper door **48** is not opened until the damper **55** has been opened to relieve pressure in the upper combustion chamber **42**.

During production, the boiler **30** is moved around by means of a hook, illustrated at **650** (FIG. **16**), attached to the outer casing **36**. When the regulator housing **300** is thereafter installed, this hook **650** is rendered unavailable. Referring to FIGS. **5**, **14**, **19**, and **26**, the housing **300** is provided with a removable panel **652** (for example, 10 inches by 10 inches) to allow the installer the ability to gain access to the hook **650** to move the boiler **30** around and thus make their installations easier.

Referring to FIG. **34**, there is illustrated at **660** an optional thermal storage tank which it has been suggested may be installed, if desired, to store heat energy during low heat usages for use during peak heat usage times. The tank contains water, illustrated at **662**, which remains in the tank **660** and copper coils for transferring heat from the boiler **30** to the water **662** for storage thereof and for transferring heat from the water **662** for usage thereof, allowing the boiler **30** to run at full capacity yielding the most efficient burn with the least amount of produced emissions. The tank **660** has a boiler side coil **664** for receiving heated water from the boiler **30**, via line **666**, as illustrated at **670**, when valve **668** is open (and valve **672** closed), and in heat exchange with the tank water **662**, delivering heat therein to the tank water **662** for storage of the heat. The heat depleted water from coil **664** is then returned to the boiler **30** via line **674**, as illustrated at **676**, to be re-heated. When heat in the tank water **662** is to be used, water is flowed through use side coil **678** via inlet and outlet lines, illustrated at **680** and **682** respectively, as illustrated at **684**, with inlet and outlet valves **686** and **688** respectively open and valve **672** closed, with the water **662** giving up its heat to the water flowing through the coil **678** in heat exchange relation therewith for use. Heated water from the boiler **30** may be directed used by closing valves **668**, **686**, and **688** and opening valve **672**. The heat storage tank **660** may be of any suitable size and shape and construction, for example, one marketed by STSS Co., Inc. of Mechanicsburg, Pa. and one marketed by Bioheat USA of Lyme, N.H.

It should be understood that, while the present invention has been described in detail herein, the invention can be embodied otherwise without departing from the principles thereof, and such other embodiments are meant to come within the scope of the present invention as defined by the appended claims.

What is claimed is:

1. A boiler comprising an inner casing, an outer casing defining with said inner casing a space in which fluid can be received for heating thereof, a fluid inlet to the space, a fluid outlet from the space, a refractory structure in said inner casing and defining an upper combustion chamber and a lower combustion chamber in said inner casing, at least one vertical passage through said refractory structure for flowing combustion gases from said upper combustion chamber to said lower combustion chamber, at least one first forced air inlet to said upper combustion chamber for providing oxygen for burning of material in said upper combustion chamber, at least one forced air passage in said refractory structure and opening into said vertical passage thereby providing at least one second forced air inlet to said vertical passage for providing oxygen in said vertical passage for burning of the combustion gases and particulates passing therethrough from said upper combustion chamber, wherein said refractory structure extends entirely across and sealingly engages said inner casing in a manner to seal said upper combustion chamber from said lower combustion chamber so that said upper combustion chamber can be made substantially air tight whereby said upper combustion chamber can be pressurized by forced air thereto to effect expulsion of combustion gases and particulates from said upper combustion chamber through said at least one vertical passage for burning thereof, and refractory material disposed in said lower combustion chamber and having an upper surface positioned so that the burning combustion gases and particulates expelled through said at least one vertical passage impinge on said upper surface.

2. A boiler according to claim **1** further comprising an exhaust passage including at least one flow restricting tube.

3. A boiler according to claim **1** further comprising a pump connected for pumping the fluid from the fluid outlet directly to the fluid inlet.

4. A boiler according to claim **1** wherein both of said inner and outer casing are composed of the same material.

5. A boiler according to claim **1** wherein both of said inner and outer casing are composed of boiler plate having a thickness of at least about ¼ inch.

6. A boiler according to claim **1** further comprising doors hingedly attached to the boiler to open and close said upper and lower combustion chambers respectively, wherein at least one of said doors comprises a first plate having an outer surface which defines an exterior of the door and having an inner surface, a second plate spaced inwardly from said first plate and having inner and outer surfaces, a block of refractory material attached to said inner surface of said second plate, and insulation material disposed between said first and second plates.

7. A boiler according to claim **1** further comprising a damper which is closable to thereby seal said upper combustion chamber and which is openable to relieve pressure in said upper combustion chamber, a rod connected to said damper and having a handle for pushing and pulling said rod for opening and closing said damper, a door to said upper combustion chamber, a handle pivotally attached to said door for opening and closing said door, and members on said rod and said door handle respectively which are engageable when said door is closed to prevent movement of said door handle to open said door when said rod is in a position such that said damper is closed and which are disengagable to allow movement of said rod to a position opening said damper.

8. A boiler according to claim **1** further comprising at least one forced draft fan for supplying air to said first and second forced air inlets, at least one electric motor for operating said at least one forced draft fan, and means for operating said electric motor between a first speed for increasing the liquid temperature to a set point temperature and a second speed which is a reduced speed for maintaining combustion without the liquid temperature being increased above the set point temperature.

9. A boiler according to claim **1** wherein said refractory structure includes at least one layer of laid refractory material containing said at least one forced air passage, a block of refractory material set into said laid refractory material and containing said vertical passage, and a plurality of blocks of refractory material set into said laid refractory material and defining an upper refractory structure surface for receiving wood or biomass.

10. A boiler according to claim **1** wherein said refractory structure includes at least one layer of laid refractory material containing said at least one forced air passage, a first block of refractory material set into said laid refractory material and containing said vertical passage, and a plurality of second blocks of refractory material set into said laid refractory material and defining an upper refractory structure floor for receiving wood or biomass and which slopes upwardly from said first block toward said inner casing in a manner to prevent bridging of the wood or biomass.

11. A boiler according to claim **10** wherein said floor extends upwardly over a distance of less than about 2¼ inches.

12. A boiler according to claim **1** wherein said refractory material upper surface is inclined downwardly form rear to front of the boiler.

13. A method of heating a fluid comprising the steps of:

(a) providing a fuel in an upper combustion chamber which is within an inner casing, wherein the upper combustion chamber is sealingly separated from a lower combustion chamber within the inner casing by a refractory structure which has at least one vertical passage which allows flow of combustion gases and particulates from the upper combustion chamber to the lower combustion chamber;

(b) flowing a fluid to be heated through a space between the inner casing and an outer casing to thereby receive heat through the inner casing;

(c) initiating burning of the fuel;

(d) effecting sealing of the upper combustion chamber;

(e) providing a forced air flow to the upper combustion chamber thereby providing oxygen for burning the fuel and thereby expelling combustion gases and particulates from the sealed upper combustion chamber downwardly through the at least one vertical passage;

(f) providing a forced air flow through at least one passage in the refractory structure to the at least one vertical passage to effect burning of the combustion gases and particulates being expelled therethrough; and

(g) effecting impinging of the burning combustion gases and particulates on refractory material in the lower combustion chamber.

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