An air heating device includes two closed conduits, one conduit for the flow of the air supply to a combustion furnace and the other for the flow of exhaust gas from a combustion furnace to a flue. The conduits pass through and around each other multiple times in an interweaving pattern such that the entirety of either conduit is almost completely surrounded by the other conduit, to maximize contact area and thermal energy transfer between the conduits relative to the device size and no use of small tubes or passageways. The shapes and pattern of the two conduits resembling the appearance of a sine wave and cosine wave drawn on the same X axis.
Fig. 1 Side sectional view

Fig. 2 Top sectional view

Exhaust Gas Flow

Air flow
Fig. 3 3D view portion of invention device
Fig. 4 Air guides

---

Exhaust Gas Flow

Air flow
DEVICE FOR HEATING AIR DURING THE DUTY CYCLE OF A COMBUSTION FURNACE

CROSS REFERENCE TO RELATED APPLICATIONS


BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a device for heating air during the duty cycle of a heating boiler, especially central heating water boilers fired by solid fuel or biomass.

2. Description of the Related Art

Polish Pat. Appl. No. P 378703 refers to an environmentally friendly central heating water boiler fired by solid fuels, especially wood and coal, designed for providing central heating in residential houses and other objects. The water jacket surrounding the combustion chamber, housed within the boiler's body, is additionally heated from the outside by exhaust gas which escapes through exhaust gas partitions surrounding the water jacket. The exhaust gas partitions are thermally insulated by chamotte bricks and mineral wool wattings.

Another known device mentioned in Polish Pat. Appl. No. P 380100 refers to a method of combustion and a combustion boiler which reduces the emission of nitrogen oxides in the exhaust gas from the solid fuel boiler with a retort burner by decreasing the temperature at the flame core. This is achieved using a stream of re-circulated exhaust gas, a mixture of exhaust gas and air, steam or a mixture of steam and air flowing to the retort burner or to the combustion chamber directly over the flame, pumped by a fan through a moving recirculation pipe, nozzles installed in the boiler's ceiling, or nozzles located around the retort burner, or through the combined solutions.

A water boiler for solid fuel, especially for biomass, known from Polish Pat. Appl. No. P 381102, is fitted with a body and a vault housing a water jacket, under which the combustion chamber is located. The vault housing the water jacket is connected to the water chamber of the boiler's body. Lower arm sections of the body are fitted with conduits for a portion of overfire air, whose volume is adjusted by rotary flaps actuated by the lower electric stepper motor. The upper section of the recuperation combustion chamber is fitted with an inlet conduit for additional overfire air, whose volume is adjusted by a flap actuated by the upper electric stepper motor. The grate tubes located under the vault with the water jacket are cooled using water and cleaned by scrapers between the grate tubes driven by a linear electromagnetic drive unit. The exhaust gas collector is fitted with an oxygen probe which controls the stepper motors to ensure a very low level of toxic substances in the exhaust gas. To ensure ease of operation for the user, the boiler can be fitted with an automatic fuel feeder and a laser sensor for detecting whether a specific upper fuel level in the recuperation combustion chamber has been reached, as well as a second laser sensor for detecting whether the lower fuel level in the recuperation combustion chamber has been reached and for actuating the automatic fuel feeder.

Another known device mentioned in Polish Pat. Appl. No. P 381355 refers to a central heating water boiler fitted with a system for supplying primary and overfire air to the combustion chamber. The system is composed of pumping nozzles on the boiler's sides. The nozzles work with a blow-in fan installed in the air conduit pumping the air into the area between the water jacket and the outer jacket. The pumping nozzles are in the form of fixed tubes installed between the walls of the water jacket and they connect the combustion chamber with the area between the water jacket and the outer jacket. The number of the pumping nozzles depends on the boiler's size and capacity.

Polish Pat. Appl. No. P 368210 refers to a heating boiler fitted with a furnace chamber and a furnace, a blower for supplying compressed air and a fuel feeder. In the chamber's upper section, there is a heat exchanger in the shape of a boiler drum with internal rings formed by the fitted vertical exhaust pipes. The pipes located radially around the longitudinal axis of the heat exchanger and in the water jacket, with at least one external ring formed by exhaust pipes whose outlets are connected directly to the boiler's flue section and inlets located over the furnace chamber, below the outlets, forming at least one internal ring of exhaust pipes, whose inlets are located in the exhaust gas return chamber.

Another device known from Polish Pat. Appl. No. P 376356 refers to a water boiler fired with hard coal. The boiler is fitted with a heat exchanger with two retort furnaces supplied with fuel through the symmetrical and separate coal supply systems. The air required for the combustion process is supplied to the furnace through a symmetrical, double primary air system. The air supplied over the furnace comes through a symmetrical, double overfire air system. These systems are actuated by separated fans. The heat exchanger is connected to the exhaust gas fan through a multicyclone.

Another known device mentioned in Polish Pat. No. 196625 refers to exhaust gas boiler, especially fitted with a fan assembly, with a drive motor, suction fan installed on the rotary shaft of the drive motor, located in the suction conduit, ensuring forced induction of air from the room or from the outside, and an exhaust fan installed on the rotary shaft of the drive motor, located in the outlet conduit to ensure forced removal of exhaust gas outside. Thus, the air from the room or from the outside is forced into the intake conduit by the suction fan, and the exhaust gas is forced into the outlet conduit by the exhaust fan. The method ensures a constant air flow in the intake, combustion and outlet conduits.

A device known from Polish Pat. No. 192574 refers to a boiler with a retort furnace with an extended heating surface. The boiler is an environment-friendly device. It has a two-level furnace and an extended heating surface for producing heat from solid fuels. The two-level retort furnace is fitted with air slots, and the symmetrical construction of the collector allows the boiler to be supplied with fuel and air from the right side as well as the left side. The heat exchanger, composed of multiple parts, forms a single water unit and includes a lower section around the furnace, a middle section formed by the boiler drum with pipes, an upper section around the exhaust gas collector and an external part which forms passage pockets. The whole boiler is a uniform, welded construction.
Polish Pat. No. 188246 refers to a heating boiler with gasification, fired by solid fuel, especially wood. The heating boiler has a fuel and gasification chamber, with a cross-section in the shape of a pear, which converges in the middle, in the peak line. In the peak line area and in the middle, there is a slotted grate with a length of approx. 1/3 of the peak line. Over the grate, there are primary air inlet openings on both sides, at approx. 0.4-0.6 of the maximum height of the fuel and gasification chamber. Under the grate, a slotted combustion nozzle is installed. It is roughly equal in length to the grate and constitutes a connection with the combustion chamber. The combustion chamber is divided by a slightly inclined horizontal wall into pre-combustion and mixing chamber and a post-combustion chamber located underneath. The cross-section of both chambers resembles the shape of kidneys, widening in the flow direction. The pre-combustion and mixing chamber is supplied with overfire air supplied by the air supply pipe and air heater. At the outlet of the pre-combustion and mixing chamber, and at the inlet of the post-combustion chamber, there is a return and post-combustion chamber. Between the outlet of the post-combustion chamber and the exhaust gas lines, there is another post-combustion chamber, through which a supply pipe for overfire air is guided to the air heater.

SUMMARY OF THE INVENTION

The invention provides a heat exchanging device to increase the efficiency of the duty cycle of a combustion furnace, fired in particular by solid fuel or biomass, by recycling thermal energy from the exhaust gas flow to a flow of heated air supplied to the furnace combustion chamber. The device is comprised of two hermetically sealed metal conduits: an air conduit connected at one end to an air intake vent and at the other end to the air supply to a furnace combustion chamber and an exhaust gas conduit connected at one end to the exhaust gas flow from a furnace and at the other end to a flue. The entireties of both conduits, each being several times longer than the device itself, are contained within the device. External conduits connect the device to the furnace. The air and exhaust gas, via their respective conduits, flow through the device in opposite directions.

Each conduit is comprised of a series of parallel, rectangular prism shaped, vertical chambers, each with a depth similar to the full depth of the invention device, disposed in an alternating pattern so that, with the exception of the vertical chambers at either end of the invention device, each vertical air conduit chamber is sandwiched between two essentially contiguous vertical exhaust gas conduit chambers and each vertical exhaust gas conduit chamber is sandwiched between two essentially contiguous vertical air conduit chambers. Each vertical air conduit chamber and substantially contiguous vertical exhaust gas conduit chamber share the same vertical wall. The widths of the chambers comprising the air conduit increase progressively in the direction of the air flow, resulting in the physical volume of the air conduit increasing in the direction of the air flow. The widths of the chambers comprising the exhaust gas conduit decrease in the direction of the exhaust gas flow, resulting in the physical volume of the exhaust gas conduit decreasing in the direction of the air flow.

The series of chambers comprising either conduit are connected in a manner such that the two conduits pass through and around each other multiple times, alternately, near the upper and lower ends of the vertical chambers, in an interwoven pattern. Each passing of the conduits through and around each other is enabled by a mesh style connection comprised of short horizontal air ducts connecting two vertical air conduit chambers by passing through the exhaust gas conduit chamber located between. At each mesh style connection, air flows through the horizontal ducts from one air conduit chamber into the next air conduit chamber as exhaust gas passes vertically between the horizontal ducts before flowing around, alternatingly, the upper or lower end of the adjacent vertical air conduit chamber and into the next exhaust gas conduit chamber. The interweaving of the two conduits through and around each other throughout the device results in either conduit being almost entirely surrounded by the other conduit, to maximize contact area between the conduits without use of small tubes or passageways that would be subject to fouling with combustion soot. The large contact area provides a high level of thermal energy transfer between the conduits. The design of the exhaust gas conduit from a series of chambers, and without any small tubes or passageways, enables easy cleaning access to the entire exhaust gas conduit interior by placement of narrow vertical doors along one outside edge of each vertical exhaust gas conduit chamber.

The interweaving pattern of the two conduits throughout the device generally resembles the appearance of a sine wave and a cosine wave drawn together on the same x axis.

A variable speed pumping fan connected to the air conduit assists the air flow through the air conduit and into the furnace as well as the exhaust gas flow from the hermetically sealed furnace to the device and through the exhaust gas conduit into the flue. Air guides mounted to the inside walls of each vertical air and exhaust gas conduit chamber enhance thermal energy transfer between the air and exhaust gas flows and the conduit walls by increasing the surface area of the walls and the circulation of the gas flows against the walls. Drain outlets at the lower portions of the exhaust gas conduit chambers enable release of condensate resulting from the decrease of the exhaust gas temperature while passing through the conduit. The outer walls of the device are insulated to reduce heat leakage to the outside.

The heated air is channeled from the device via an external conduit to the furnace combustion chamber's ashpan. The recycled thermal energy typically increases furnace efficiency by 20%-50%, with a corresponding increase in the furnace's useful heat generating capacity. Alternatively, the air heated by the device can be used for space heating or another purpose. The invention can be used in industrial boiler rooms or for recovering heat from other devices or processes releasing a heated gas, such as the spent steam from a steam turbine. The thermal heat transfer efficiency and fuel savings levels have been confirmed by technical tests and practical use.

Environmental benefits of the invention when used with a combustion furnace are reduced carbon based fuel combustion to generate a given amount of useful thermal energy, an approximate 90% reduction of heat released via the flue into the atmosphere, and significant filtering of pollutants from the exhaust gas before emission into the atmosphere. Filtered pollutants include particulate matter, heavy metals, sulfur, and other elements generally emitted by combustion furnaces fired by solid fuels or biomass. Laboratory testing with an industrial coal furnace confirmed filtering of particulate matter from the exhaust gas flow at the 98+ percent
level. Filtered pollutants are automatically washed from the device with the condensate that forms in the exhaust gas conduit chambers or remain deposited inside the exhaust gas conduit chambers in the form of a fine, dry powder that can be removed as required.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The invention is described hereinbelow with reference to the accompanying drawings, in which FIG. 1-4 show an exemplary embodiment of the device for heating air during the duty cycle of a combustion furnace.

[0022] FIG. 1 shows a sectional side view of one embodiment of the device, which comprises a closed conduit through which air flows (smaller arrow) before being supplied to a furnace combustion chamber (8) and a closed conduit through which exhaust gas from a combustion furnace (1) flows before passing through a flue (4) into the atmosphere. In the depicted embodiment, the air conduit (6) defines a shape resembling a sine wave and is comprised of a series of connected, rectangular prism shaped, vertical conduit chambers. The exhaust gas conduit (2) of a shape resembling a cosine wave is comprised of a second series of connected, rectangular prism shaped, vertical conduit chambers. Except for the conduit chambers at either end of the device, each vertical air conduit chamber is sandwiched between two essentially contiguous vertical exhaust gas conduit chambers, and each vertical exhaust gas conduit chamber is sandwiched between two essentially contiguous vertical air conduit chambers. Me9h-type connections (3) located, alternately, near the upper or lower sections of the vertical conduit chambers, enable the conduits to pass through and around each other at each such connection. The mesh connections are shown in greater detail below.

[0023] A pumping fan (5) located near the intake at the beginning of the air conduit assists the air flow through the air conduit (6) and from the invention device to the furnace combustion chamber (8). In one embodiment, the exhaust gas flows from the furnace (1), is hermetically sealed to the invention device and exits the device via the exhaust gas conduit (2) via the flue (4).

[0024] FIG. 1 shows that the widths of the vertical chambers comprising the air conduit (6) increase progressively in the direction of the air flow, thereby progressively increasing the physical volume of the air conduit to accommodate expansion of the air as its temperature increases while passing through the conduit. On the other hand, the widths of the vertical chambers comprising the exhaust gas conduit (2) decrease progressively in the direction of the exhaust gas flow, thereby progressively decreasing the physical volume of the exhaust gas conduit to accommodate contraction of the exhaust gas as its temperature decreases while passing through the conduit.

[0025] FIG. 1 shows drain outlets (7) fitted at the lower portions of each exhaust gas conduit chamber to enable release of condensate that forms as the temperature of the exhaust gas decreases while flowing through its conduit.

[0026] Many pollutants from the exhaust condensate are removed from the device through the drain outlets (7). As shown in FIG. 1, in one embodiment pollutants are significantly filtered from the combustion exhaust gas flow at a filtering point (12) before passing via the flue into the atmosphere, with filtered pollutants including particulate matter, sulfur, heavy metals, and other elements typically emitted by combustion furnaces fired by solid fuel or biomass.

[0027] FIG. 2 shows a top sectional view at the plane of the horizontal broken line in FIG. 1, to illustrate mesh connections (3) located near the upper sections of the vertical conduit chambers. Each mesh connection shown is comprised of three horizontal air ducts passing through an exhaust gas chamber while allowing the exhaust gas flow to pass vertically between the air ducts. The mesh connections at the lower sections of the vertical conduit chambers are only partially visible.

[0028] FIG. 3 shows a 3-dimensional, angled view of a portion of the entire device shown in FIG. 1, to more clearly illustrate the mesh connections where air flows through horizontal ducts (9) connecting two vertical air conduit chambers (6) as exhaust gas passes vertically between the horizontal ducts and around, alternately, the upper or lower end of the adjacent air vertical conduit chamber and into the next vertical exhaust gas conduit chamber.

[0029] FIG. 4 is a side sectional view of a portion of the invention device showing the air guides (10) mounted to the inside walls of the vertical air and exhaust gas conduit chambers. Arrows simulate the effect of the air guides on the circulation of the air and exhaust gas flows through the conduit chambers. The air guides are bent downwards to enable easier cleaning of accumulated soot from the exhaust gas conduit chambers.

[0030] As can be appreciated from the figures, in one embodiment, the device is designed such that the exhaust gas conduit forms a series of rectangular prism shaped chambers. The exhaust conduit does not use any small tubes or passageways. This design enables easy cleaning access to the entire exhaust gas conduit interior via placement of narrow vertical doors along one side edge of each vertical exhaust gas conduit chamber. In one embodiment the device includes a cleaning cycle wherein the exhaust conduit is disconnected from the furnace and a fluid or gas is pumped into the exhaust conduit, collecting through the drain outlets (7).

[0031] This invention is not to be limited to the specific embodiments disclosed herein and modifications for various applications and other embodiments are intended to be included within the scope of the appended claims. While this invention has been described in connection with particular examples thereof, the true scope of the invention should not be so limited since other modifications will become apparent to the skilled practitioner upon a study of the drawings, specification, and following claims.

[0032] All publications and patent applications mentioned in this specification are indicative of the level of skill of those skilled in the art to which this invention pertains. All publications and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication or patent application mentioned in this specification was specifically and individually indicated to be incorporated by reference. The embodiment of the invention in which an exclusive property or privilege is claimed is defined as follows:

1. A two closed conduit device comprising one conduit for the flow of the air supply to a combustion furnace and a second conduit for the flow of exhaust gas from a combustion furnace to a flue, wherein the conduits pass-through and around each other multiple times in an interweaving pattern such that the entirety of either conduit is substantially surrounded by the other conduit, to maximize contact area and thermal energy transfer between the conduits relative to the device size wherein the exhaust conduit does not use small
tubes or passageways; further wherein the shapes and pattern of the first conduit resembling the appearance of a sine wave and the second conduit a cosine wave drawn wherein each wave is drawn on the same horizontal axis.

2. The device of claim 1, wherein the widths of the vertical air conduit chambers progressively increase in the direction of the air flow and the widths of the vertical exhaust gas conduit chambers progressively decrease in the direction of the exhaust gas flow.

3. The device of claim 1, wherein air guides are disposed on the inside walls of the vertical air and exhaust gas conduit chambers to increase thermal energy transfer between the air and exhaust gas flows and the conduit walls by increasing the surface area of the walls and the circulation of the air and exhaust gas against the walls.

4. The device of claim 1, wherein each passing of the air and exhaust gas conduits through and around each other is enabled by a mesh style connection comprised of horizontal air ducts connecting two vertical air conduit chambers through a vertical exhaust gas conduit chamber without impeding the vertical flow of the exhaust gas through the chamber.

5. The device of claim 1, wherein the efficiency of the thermal energy transfer from the exhaust gas flow to the air flow, relative to the size of the device, is of a level to make recycling of energy back to the furnace as preheated combustion air a mechanically and economically attractive energy saving technique.

6. The device of claim 1, wherein pollutants are significantly filtered from the combustion exhaust gas flow before passing via the flue into the atmosphere, with filtered pollutants including particulate matter, sulfur, heavy metals, and other elements typically emitted by combustion furnaces fired by solid fuel or biomass.

7. The device of claim 1, wherein the design of the exhaust gas conduit from a series of rectangular prism shaped chambers, without use of small tubes or passageways, enables easy cleaning access to the entire exhaust gas conduit interior via placement of narrow vertical doors along one side edge of each vertical exhaust gas conduit chamber.