A fluid fuel burning device, comprising: an elongated combustion compartment comprising side walls, where distal end is open allowing fluid communication from inside the combustion compartment and out of compartment; an insulation layer arranged on the inner surface of the side walls and/or on an inner surface of the proximal end of the compartment, preventing heat inside the compartment from radiating away from the compartment from the side walls and/or the proximal end, air flow means for providing a current of air, a fuel nozzle for aeration of the fluid fuel inside the combustion compartment, fuel feeding means for feeding fluid fuel to the fuel nozzle, pressure providing means for applying pressure to the fluid fuel fed via the fuel feeding means, and where the insulation layer comprises a heat absorbent layer that is of a temperature retentive material and radiating heat from the absorbent layer into the combustion compartment.
Fig. 5c
FLUID FUEL BURNING DEVICE

FIELD OF THE INVENTION

Background

[0001] Burners are devices that are commonly used to generate a flame to heat up products using different kinds of fuel, such as coal, wood, gas or oil. Thus, a burner may be used to heat up water to provide warm water or steam, which may be used for heating purposes and/or electrical energy production.

[0002] In recent years, there has been a continuous increase in national and/or international regulations that dictate how efficient the burners have to be and regulations that limit the allowed amount of discharge of pollutants in order to improve the air quality and to limit the emissions of greenhouse gases resulting from the burn. Furthermore, one of the most significant issues with regard to fuel burners is the burner efficiency, especially when the fuel for the burner utilises fuels that are of a relatively low calorific value, as low calorific value may reduce the cleanliness of the burning process.

[0003] An important issue with burners is that in order to obtain an effective burn, it is important that the fuel is burnt at a predefined temperature that is optimal for the specific kind of fuel. One of the factors that may lead to reduced cleanliness of the burn process is that the chamber of a burner may be constructed in such a way that the temperature inside the chamber varies, i.e. where a certain volume inside the chamber may have a lower temperature than other volumes inside the chamber. This means that in the lower temperature volume of the burner, the burning process is not as effective as another volume of the chamber that is most effective as it has the correct temperature.

[0004] A burner is usually constructed in such a way that the walls of the burner define the burning chamber. A common problem with burning chambers is that the peripheral areas of the chamber, i.e. the areas close to the walls are cooler than the central area of the chamber. The cooler areas may result from a number of different reasons, such as poor insulation of the walls or the size of the flame inside the chamber, relative to the size of the chamber. This may especially be the case, when the burner is a fluid burner, where the fuel is a hydrocarbon based fuel either in liquid and/or gaseous form. This means that the chamber may be filled with fuel vapours that spread inside the chamber, and the varying temperature inside the chamber means that some of the vapour may be burnt at a lower temperature than others, and thereby reducing the efficiency of the burn, as not all of the molecules of the fluid fuel are incinerated. The varying temperature inside the chamber means that some of the hydrocarbons may escape the burn chamber without being fully incinerated, i.e. partly incinerated, and the efficiency of the burner may be reduced.

[0005] The reduced efficiency is particularly evident when the hydrocarbon base fuel may be part of a fuel mixture that may be of a low calorific value, i.e. where the fuel does not burn well. A fuel mixture of low calorific value may be waste material that has a low calorific value and high water content or up to 40%. A traditional burner is not well equipped to incinerate such a fuel mixture, and by attempting to burn the mixture, it will result in a large amount of soot and/or NOx particles.

[0006] US patent application 2005/0048426 A1 shows a gasification burner using high-pressure swirled air. The inner surface of the combustion chamber is made of a refractory material such as ceramic, so that heat conduction from the combustion chamber to the housing of the burner is prevented by insulating the outside from the inside.

[0007] Thus, there is a need for a burner device that has an even temperature and incinerates fluid fuel efficiently having relatively clean emissions, where the optimum incinerating temperature for the specific fluid fuel mixture may be substantially maintained within the burn chamber of the burner.

GENERAL DESCRIPTION

[0008] In accordance with the invention, there is provided a fluid fuel burning device, comprising: an elongated combustion compartment, comprising side walls having an outer surface and an inner surface, defining the radial periphery of the combustion compartment, having a central axis extending from a proximal end to a distal end of the compartment in the longitudinal direction, where distal end is open allowing fluid communication from inside the combustion compartment and out of the compartment; airflow means for providing a current of air in a direction from the proximal end of the combustion compartment and towards the distal end in a direction parallel to the central axis of the compartment; a fuel nozzle for delivery of fuel fluid inside the combustion compartment; fluid feeding means for feeding fluid fuel to the fuel nozzle; pressure providing means for applying pressure to the fluid fuel fed via the fuel feeding means; a thermal insulation layer arranged radially between the central axis of the combustion compartment and the side walls of the compartment, reducing the heat transfer in a direction from the central axis of the combustion compartment towards the side walls; wherein the fluid fuel burning device further comprises a thermal absorbent layer arranged radially between the central axis of the combustion compartment and the thermal insulation layer, allowing thermal energy generated within the combustion compartment to be absorbed and radiated back into the combustion compartment in a direction towards the central axis; when thermal equilibrium has been reached between the combustion compartment and the thermal absorbent layer.

[0009] By ensuring that the side walls of the combustion compartment are both provided with an absorption layer and an insulation layer, the thermal dissipation of heat from inside the compartment is reduced through walls of the device. Thus, it is possible to ensure that inner volume inside the combustion compartment and/or combustion chamber has an evenly spread temperature, where the volume of the central area of the compartment has a heat signature that is similar to those parts that are close to the side walls.

[0010] Furthermore, the temperature retentive thermal absorbent layer is capable of heating up to a temperature that is substantially equal to the temperature inside the combustion compartment during fuel burning/combustion. This means that the thermal absorbent material may be further utilized to emanate heat from the absorbent material and into the combustion compartment, so that the temperature difference between the inner volume of the compartment and the absorption layer is minimal. This ensures that the inner surface area of the compartment does not provide “cold” or cooler areas inside the combustion compartment, ensuring that the fuel being burned inside the compartment is burnt at substantially the same temperature across the entire cross sectional diameter of the combustion compartment.

[0011] The heat absorbent layer may be heated up by the heat generated inside the combustion compartment. This
means that when the volume of the combustion compartment reaches a temperature, the absorbent layer will heat up until it reaches substantially the same temperature as the combustion compartment, and the heat absorbent layer will radiate heat back to the combustion compartment. Thus, when the heat absorbent material will reach a temperature that is close to or substantially the same as in the combustion compartment, an equilibrium of heat transfer will occur between the heat absorbent material and the combustion compartment, i.e. when heat is radiated from the heat absorbent layer into the combustion compartment, the combustion compartment will transfer heat energy back to the absorbent layer in order for the heat absorbent layer to maintain its temperature.

[0012] The even temperature inside the compartment in combination with the aerification nozzle, ensures that the vast majority of the fuel particles injected into the compartment are burnt at substantially the same temperature, ensuring that none of the particles are only partly burnt, when the temperature inside the compartment is at a predefined optimum temperature. The predefined temperature may be around 1000°C for a specific type of fuel, while the optimal temperature may vary anywhere between 600-1400°C, or in accordance with an EU regulation directive at least 800 or higher, where the optimal temperature for a specific type of fuel may be chosen based on trial and error experimentation and measurement of the waste matter content in the exhaust gasses. If the temperature exceeds approximately 1150°C, the oxidation may begin to produce significantly more NOx particles, which are unwanted, where the temperature 1150 may be an upper limit for the device.

[0013] Thus, when the predefined temperature inside the compartment is around 1000°C. for a specific type of fuel, and the fuel inside the central area of the combustion compartment is being oxidized at approximately 1000°C, the insulation material arranged in the radial peripheral area of the compartment is approximately at the same temperature, ensuring that the entire volume, from the central area to the peripheral area of the cross sectional diameter of the compartment, is at substantially the same temperature.

[0014] The heat absorbent layer of the insulation material may be warmed up to its temperature by a burning inside the combustion compartment, and thus the temperature of the insulation will not exceed the combustion temperature. However, during the burning process, the insulation material will absorb heat from the combustion compartment until a maximum temperature is reached. When the maximum temperature is reached, the insulation material may supply radiant heat that emanates from the insulation material and into the combustion compartment.

[0015] The insulation material may retain a temperature level that may be slightly lower than the temperature inside the combustion compartment, where the temperature may be approximately 0.01-5% lower, ensuring that there is minimal temperature difference between any central area of the combustion compartment and the inner walls of the compartment.

[0016] The thermal absorption layer may be an energy accumulating material, so that the side walls of the compartment furthermore provides heat to the sides of the compartment. The heat inside the compartment may be higher than necessary to obtain the optimum burn, so that it is ensured that the heat at the inner walls of the compartment is at least as high as necessary to obtain the optimum temperature.

[0017] Furthermore, the device may further comprise a heat transfer reduction layer or a thermal insulation material that is positioned in a radially outward position relative to the heat absorbent material, i.e. at the surface of the heat absorbent material facing away from the combustion compartment. The heat transfer reduction layer ensures that the heat absorbed by the heat absorbent material is easily transferred in a direction away from the combustion chamber, i.e. the heat transfer reduction layer reduces the heat transfer from the heat absorbent layer, and out of the fuel burning device.

[0018] Within the meaning of the present invention, the meaning of the term “thermal absorption layer” may be seen as layer of a material that has a high thermal conductivity, or approximately between 1.2-3.05 W/m-K ASTM C 182 at 800°C. More specifically the thermal conductivity may be between 1.3 and 2.5 W/m-K ASTM C 182 at 800°C, even more specifically between 1.5 and 2.4 W/m-K ASTM C 182 at 800°C.

[0019] Within the meaning of the present invention, the meaning of the term “thermal insulation layer” may be seen as layer of a material that has a low thermal conductivity, or approximately between 0.1-0.5 W/m-K ASTM C 182 at 800°C. More specifically the thermal conductivity may be between 0.1 and 0.35 W/m-K ASTM C 182 at 800°C, even more specifically between 0.15 and 0.24 W/m-K ASTM C 182 at 800°C.

[0020] Within the meaning of the present invention the term “insulation material” may be understood as being at least one layer of thermally absorbent material, and at least one layer of thermal insulation material.

[0021] The fuel nozzle may be arranged close to the longitudinal axis or the central axis of the compartment, i.e. at the radial centroid of the compartment, so that the distance from the side walls to the nozzle is substantially the same when measured in any direction.

[0022] This means that when the fuel is aerified inside the compartment, the flame will be distributed substantially along the entire cross sectional diameter of the compartment, and the fuel may oxidize at any radial distance from the nozzle. The fuel is injected into the compartment under pressure, ensuring that the fuel particles are distributed evenly in a radial and/or longitudinal direction away from the nozzle. The fuel nozzle ensures that the fuel particles are mixed with the air being introduced through the air inlet, so in order to increase the surface area of the fuel, when the fuel is injected in the compartment.

[0023] In an alternative embodiment, the burner may be provided with more than one nozzle, i.e. two, three, four or more nozzles, where the amount of nozzles has to be adjusted so that the aerified fuel distribution inside the compartment is substantially even, so that the fuel may be burnt at any radial position inside the compartment without risking that the burn is not performed at the optimal temperature.

[0024] In order to ensure that the burn process is performed at an even predefined temperature from the start, the ignition element may be used to preheat the inner volume of the compartment. This may be done to ensure that when the flow of fuel into the compartment is commenced, and the fuel burn is started, the temperature is as close to the predefined temperature as possible, in order to ensure that the burn is as optimal as possible throughout the entire burning process.

[0025] Air flow is provided inside the compartment, where the air flow may be extended from the proximal end and towards the open end, and where the magnitude of air flow may be used to control the temperature inside the compartment along with the fuel flow, and to provide a source of
oxygen for the burning process. The air may be preheated before it is injected into the compartment, so that the air flow does not reduce the temperature inside the compartment. However, in order to reduce the temperature inside the compartment, the air may be introduced into the compartment without pre-heating and the relative low temperature of the air may influence the temperature inside the compartment to be reduced.

Thus, by having an even temperature inside the combustion chamber of the fluid fuel burning device, the device may burn as many hydrocarbons as possible, and thus reduce the hydrocarbon pollution as much as possible. Such a fluid fuel burning device may have a clean burn, where the fuel is substantially a hydrocarbon based fuel, but the device does not reduce the amount of heavy metals, chlorine, sulphur, etc., and those elements may have to be reduced using further cleaning methods that may be subsequent to the fuel burning process.

In one embodiment, the device may be provided with an ignition element for heating up the inner volume of the combustion compartment to a predefined temperature and for igniting the aerated fluid fuel inside the combustion compartment.

In one embodiment of the invention, the outer surface of the combustion chamber may comprise a layer of heat transfer material. The material may be a metal, such as steel, where any heat that escapes the insulation material in a radial direction away from the combustion chamber may be radiated into the atmosphere.

In one embodiment of the invention, the pressure provided means may be configured to apply a pressure of between 1.5 bar, or more specifically between 1.1 and 3 bar or more specifically between 1.5-2 bar. This means that the pressure at which the fuel is injected into the compartment via the nozzle is relatively low. This ensures that any fuel particles that are injected into the compartment are not travelling at speeds that may exceed the time it takes to ignite the particles, i.e. that the particles do not pass the flame without being incinerated/oxidized.

In one embodiment of the invention, the elongated combustion chamber may have an inner surface area having a first cross sectional diameter, and a second inner surface area that has a second cross sectional diameter, where the first cross sectional diameter is smaller than the second cross sectional diameter. This means that the compartment may be divided into two chambers, each defined by the cross sectional diameter of the inner surface, where one of the chambers may be an combustion chamber, while the second chamber may be an exhaust chamber, or vice versa. The division of the compartment into two chambers means that the pressure inside the compartment may be changed, as the air flow passes from one chamber to the other, as the volume is either increased or decreased. This allows the gasses to expand or compress, which may have an advantageous effect on the energy extraction of the gasses to provide heating means to a second medium, such as water or steam in a boiler. In accordance with thermodynamics, a gas that expands usually drops in temperature, while gas that is compressed usually increases in temperature. This principle may be used to control the temperature of the exhaust gasses.

In one embodiment of the invention, the transition from the first cross sectional diameter to the second cross sectional diameter may have a predefined gradient in a direction that is from the proximal end towards the distal end. This means that the transition may be gradual from the first cross sectional diameter to the second cross sectional diameter, so that there are no surface areas inside the chamber that stop the flow of air or exhaust, as would be the case if the transition between cross sectional diameters would be instantaneous. Having a gradual transition may slow the air flow or the exhaust temporarily, as the gradient increases the distance a single molecule may have to travel, so that the gradient will affect the speed of the complete air flow advantageously. The complete air flow inside the compartment will speed up when the air flow is directed through a decreased diameter and will slow down when the air flow is directed through an increased diameter. If the gradient is too steep, i.e. the transition occurs over a short distance such as >45°, the transition may cause turbulence in the air flow, which may reduce the efficiency of the combustion compartment.

The first and the second cross sectional diameter may extend uniformly along a predefined length of the compartment. Where the first cross sectional diameter may extend between 3 and 7 metres, and/or the second cross sectional diameter may extend between 0.5 and 2 metres.

In one embodiment of the invention, the elongated combustion compartment may have a first right circular cylindrical volume, having a first cross sectional diameter and a second right circular cylindrical volume, having a second first cross sectional diameter that is smaller than the first cross sectional diameter.

In one embodiment of the invention, the inner surface area of the proximal end of the combustion compartment may comprise the fuel nozzle and an outlet for the fan, ensuring that the air supply envelops the fuel nozzle to feed oxygen in a direction parallel to the longitudinal axis of the compartment. This means that the air flow may be directed through the entire volume of the combustion compartment from the proximal end, and in a direction towards the distal end, and allows the air flow to exit the compartment via the open distal end. Thus, the entire compartment may be used to burn fluid fuel, where a proximal part of the compartment is used to ignite and/or burn the fuel while the distal part may be used to burn and/or release the exhaust gasses into a boiler or any type of energy converter, via the distal end.

In one embodiment of the invention, the fuel feeding means may comprise a circulating fuel arrangement, the arrangement comprising a fuel tank, a output conduit from the fuel tank, an input conduit into the fuel tank, a driving arrangement for circulating the fluid, a regulator valve for regulating the pressure inside the circulating fuel arrangement, and a fluid input means to increment the amount of fluid inside the circulating fuel arrangement. The circulating fuel arrangement circulates the fuel to be burnt from the fuel tank and into the output conduit, where the output conduit may be connected to a driving arrangement, such as a pump, which pumps the fuel from the output conduit and into the input conduit, so that the fuel may be circulated out of the fuel tank and back into the fuel tank. The output conduit or input conduit may be in fluid communication with the aerification nozzle of the device for burning fluid fuel, so that the circulating arrangement may deliver a certain amount of fuel to the device, but where any excess fuel is re-circulated into the fuel tank.

The device according to the invention has a pressure provided means for applying pressure to the fuel, to be injected into the compartment via the nozzle. The pressure provided means may be positioned in the fluid communica-
tion path between the nozzle and the circulation arrangement so that the pressure inside input and/or output conduit has to exceed the pressure applied by the pressure provided means, so that the fuel may begin to flow into the aeration nozzle. The pressure inside the circulating system may be regulated using the regulator valve, where it is closed in order to increase the pressure and opened in order to decrease the pressure inside the circulating arrangement. The pressure may furthermore be regulated, using the driving arrangement, where an increase in flow may increase the pressure while a decrease in flow may decrease the pressure. Yet further, the pressure may be manipulated inside the circulating arrangement by increasing the fluid content inside the system, by adding fluids using the fluid means.

[0037] In one embodiment of the invention, the device may further comprise oxygen measuring means, arranged in the combustion compartment and/or a pressure measuring means. The measuring means may be arranged in the vicinity of the open distal end of the combustion compartment. The oxygen and pressure measurement means, which may be arranged in the vicinity of the open distal end of the compartment, are used to measure the oxygen content and the pressure of the exhaust gasses. The resulting measurements may be used to control the pressure inside the circulating arrangement, so that any variation in oxygen content and/or pressure may be used to increase or decrease the pressure inside the circulating arrangement by controlling the regulator valve and/or the fluid intake. Thus, the measurements may be used to control the flow of fluid fuel into the aeration nozzle due to the variations in pressure inside the circulating arrangement, i.e., when the oxygen level in the exhaust gasses drops, the pressure levels in the circulation arrangement may be dropped, to reduce the flow of fuel into the nozzle, and vice versa.

[0038] In one embodiment of the invention, the pressure and/or the oxygen measuring means may have at least part control of the regulator valve.

[0039] In one embodiment of the invention, the pressure and/or the oxygen measuring means may control the magnitude of air provided by the air flow means.

[0040] In one embodiment of the invention, the circulating arrangement may be a closed circulating system. This means that when the circulation arrangement is in operation, and all valves and inlets are closed, the fuel can only exit the circulating arrangement using the fuel feeding means. This means that the inner volume of the circulating arrangement is constant, when the system is closed.

[0041] In one embodiment of the invention, the circulating system may be provided with a heat exchanger that may be used to warm up, maintain the temperature or cool down the fluid fuel, while it is being circulated. The heat exchanger may be used to manipulate the viscosity of the fluid fuel, especially when the fluid fuel is in liquid form, where the viscosity of the liquid may have an influence on the rate of flow inside the circulation arrangement and furthermore on the flow rate into the aeration nozzle. Furthermore, the heat exchanger may be used to implement an optimum temperature to the fluid fuel, where the temperature of the fluid fuel may have an influence on how flammable the fuel is when injected into the combustion compartment.

[0042] In one embodiment of the invention, the fluid input may comprise a water input means, for introducing liquid water into the circulating fuel arrangement. The liquid water may be used to increase the pressure inside the circulating arrangement by increasing the amount of fluids inside a closed volume. Furthermore, the liquid water may be used to change the viscosity of the fluid fuel, especially when the fluid is a liquid. When water is introduced into the circulation arrangement, the water may function further as a lubrication means for the conduits inside the circulation system, i.e., the water will form a film on the inner surfaces of the conduits, and facilitate the movement of the fuel through the conduits of the circulation arrangement.

[0043] In one embodiment, water may be introduced into the fuel feeding means. By introducing water into the fuel feeding means, it is possible to increase the water content of the fuel in order to control the temperature inside the combustion chamber. An increase in water content ensures that the fuel burning inside the compartment is burnt at a lower temperature than where the water content is less, i.e., if the temperature inside the combustion compartment increases above a predefined level, water may be introduced into the fuel feeding means, so that the water is fed into the combustion chamber and limits the temperature inside the combustion chamber.

[0044] The invention further comprises a method of controlling fluid fuel flow in a device for burning fluid fuel, comprising the steps of: providing an elongated combustion chamber having a proximal closed end and a distal open end; providing an air flow in a direction from the proximal closed end to the distal open end; providing an aerated fluid flow inside the elongated combustion chamber; igniting the aerated fuel inside the elongated combustion chamber; measuring the oxygen content of the exhaust gasses for the apparatus; adjusting the air flow based on the oxygen content and/or the pressure of the exhaust gasses; and adjusting the fuel flow based on the oxygen content and/or the pressure of the exhaust gasses. This means that the exhaust gasses have an input in controlling the fuel flow and/or the air flow through the device, where the effectiveness of the burning of the fuel is adapted to regulate the air/fuel mixture. Thus, when the exhaust gasses have too low oxygen content, this indicates that the fuel may not be burning at an optimum aid/fuel mixture and the fuel flow may be decreased and/or the air flow may be increased. This regulation optimises the mixture, and ensures that the fuel is burnt optimally so that the exhaust gasses utilize an optimum amount of hydrocarbons that are present in the fluid fuel.

[0045] In one embodiment of the invention, the air flow may be increased if the oxygen content drops below a first predefined percentage oxygen level. When the oxygen content drops, this may be an indication that the oxygen is consumed at too high a rate during the burning process, i.e., the effectiveness of the burn is too low, and by increasing the flow of air, the oxygen feed for the burn is at a more effective level. Furthermore, in the above situation, the device could alternatively be instructed to reduce the fuel flow, so that the fuel content drops to the air flow, so that the air/fuel mixture is adjusted to an optimum level.

[0046] In one embodiment of the invention, the fuel flow may be increased if the oxygen content exceeds a second predefined percentage oxygen level. Should the oxygen content exceed a specific predefined oxygen level, this indicates that not enough fuel is burnt at the current rate of air flow, i.e., the burn does not utilise as much oxygen as is possible in the device. Thus, by increasing the fuel flow, it is possible to make the burn more effective by feeding fuel into the fuel/air mixture. Furthermore, in the above situation, the device could
alternatively be instructed to reduce the air flow, so that the air content drops to the fuel flow, so that the air/fuel mixture is adjusted to an optimum level.

[0047] In one embodiment of the invention, the method may further comprise the step of measuring the pressure of the of the exhaust gasses for the apparatus.

[0048] In one embodiment of the invention, the air flow may be decreased if the pressure of the exhaust gasses exceeds a first predefined pressure level.

[0049] In one embodiment of the invention, the air flow may be increased if the pressure of the exhaust gasses drops below a predefined pressure level.

[0050] The air flow may be used to control the energy needed in a boiler, where the boiler may convert the heat exhaust, from the fuel burning device to a secondary energy, such as boiling water, i.e. if the pressure inside the boiler reduces, the air flow may be increased so as to increase the energy production of the fuel burning device, i.e. the air flow may be seen as the “gas pedal”, which controls the energy output of the fuel burning device. Should the pressure inside the boiler increase, the air flow may be reduced for the pressure of the boiler to decrease. In accordance with the invention, other types of energy transformers may be used to transform the heat energy from the fuel burning device to a different form of energy.

BRIEF DESCRIPTION OF DRAWINGS

[0051] The invention is explained in detail below with reference to the drawings, in which

[0052] FIG. 1 is a sectional view of a device for burning fluid fuel, in accordance with the invention.

[0053] FIG. 2 is a schematic view of a device for burning fluid fuel, in accordance with the invention, where the device comprises a fuel circulation arrangement,

[0054] FIG. 3 shows a schematic diagram of a process of a water gas shift reaction,

[0055] FIG. 4 shows a cross sectional view of a device 1 for burning fluid fuel taken along the axis IV-IV in FIG. 1, and

[0056] FIG. 5a-c shows temperature graphs for the side walls of a device, in accordance with the invention.

DETAILED DESCRIPTION OF DRAWINGS

[0057] FIG. 1 shows a sectional side view of a device 1 for burning fluid fuel in accordance with the invention. The device 1 has a combustion compartment 2, where the compartment 2 is used to burn the fluid fuel. The combustion compartment 2 may be divided into a burn/combustion chamber 3, where the actual burn of the fuel is performed and an exhaust chamber 5 allows the exhaust gasses resulting from the burn to exit the device 1. The combustion chamber 3 may have a first cross sectional diameter that is larger than the second cross sectional diameter of the exhaust chamber 5, where the transition from the first cross sectional diameter to the second cross sectional diameter is gradual in a transitional chamber/volume 4.

[0058] The combustion chamber has a proximal end 6 and a distal end 7, where the proximal end 6 has a closed end 8, and where the distal end 7 has an open end 9. Within the meaning of the present invention, the terms “open” and “closed” in relation to the ends of the combustion compartment, signifies that the content inside the combustion compartment 2 cannot exit the closed end and where the contents are supposed to exit the open end, respectively. The above terminology does not exclude that foreign elements, such as air, fuel, catalyst, etc., may be introduced into the chamber via the open and/or the closed, ends as a fuel in the burn process or in order to improve the burn process.

[0059] The side walls 12 of the combustion compartment 2 may be lined with a first insulation material 10 and/or a second insulation material 11, where the insulation material 10, 11 ensures that there is as little as possible heat loss through the side walls 12. The first insulation material is a thermal absorbent material 10, and the second insulation material is a thermal insulation layer. Furthermore, the closed proximal end 8 of the compartment 2 may be provided with one or more layers of insulation material, such as a first layer 13 and/or a second layer 14 and/or a third layer 15, where the layer(s) ensure that heat loss is minimized through the closed proximal end 8 of the combustion compartment 2, where the first layer may be a thermal absorbent layer 13, while the second 14 and third 15 may be thermal insulation layers. Thus, by insulating the side walls and the closed proximal end 8, the heat generated inside the combustion compartment can practically only escape out of the combustion compartment, via the open distal end 9 of the compartment and the heat generated inside the compartment 2, may be used to power up an energy transfer unit (not shown), such as a water boiler or similar. As the side walls 12 of the combustion chamber are lined with thermally absorbent material 10 and a thermal insulation material 11, there will be some heat loss through the side walls, and the heat loss is shown as an example in FIG. 5a-c.

[0060] The closed proximal end 8 of the compartment 2 is provided with an air inlet 16 and a fuel nozzle 17, where the fuel nozzle sprays/injects fluid fuel 18 into the inner volume of the combustion chamber, 3, and thereby aerates the fuel inside the combustion chamber 3. The fuel nozzle is in fluid connection with a fuel tank (not shown), via a fuel inlet 23, which may further be connected to a pressure providing means (not shown) that ensures that fuel is introduced into the chamber under pressure. The air inlet 16 introduces a flow of air 19 into the combustion chamber so that the air 19 flows in from the closed proximal end 8, and towards the open distal end 9. The air flow in this exemplary combustion compartment, signifies that the air 19 flows in the direction of the arrows A, inside the first cross sectional diameter of the combustion chamber 3 and where the air converges in the transitional chamber 4 in the direction of arrows B, until it exits the compartment under higher pressure, due to the convergence of the air in the transitional chamber, via the exhaust chamber 5 in the direction of arrows C.

[0061] Initially during the startup of the burning device, the combustion compartment 2 is warmed up to a predefined temperature, in order to ensure that the initial burning of the fluid fuel occurs at an optimum temperature, which ensures that the burn is as optimal as possible, i.e. the majority, if not all, of the hydrocarbons of the fluid fuel are burnt, when the fuel 18 is injected via the aerification nozzle 17 into the combustion chamber 3. The warming of the compartment may be done in various ways, where one of the methods for warming up the compartment 2 is to light an ignition element 20, which may have a dual functionality, in that the ignition element 20 is adapted to ignite the fluid fuel injected into the compartment 2, and is adapted to warm up the interior of the combustion compartment prior to the initial ignition of the fuel.

[0062] The combustion compartment 2 may be defined by an outer shell 21 of steel or other types of metal, which forms
the basis for laying the insulation material 10,11, in the form of an absorbent layer and an insulation layer, where the insulation material may be arranged on the interior surface of the outer shell 21 and/or on the outer surface of the outer shell 21. The inner insulation material 10 may be a layer of heat absorbent material, absorbing the heat from the oxidation inside the combustion chamber, while the outer insulation material 11 may be a layer of a reduced thermal transmission layer (insulation), which ensures that most of the heat from the absorption material and from the combustion chamber is kept inside the outer shell 21. The outer shell 21 may be further provided with support rings 22 that encircle the outer shell 21 radially, i.e. where the support rings 22 or support bands have an inner diameter that is substantially equal to the outer diameter of the outer shell 21. The support rings 22 strengthen the structural integrity of the outer shell 21 in a radial direction, so that any pressure variations inside the compartment 2, or similar stress/strains do not deform the outer shell 21 by bulging in or out radially.

[0063] The thermal absorption layer may be a material such as Alobrick TE200A, an andulau-site/Cordundum stone that has a high thermal conductivity, or approximately 1.6 W/m-K ASTM C 182 at 1000°C, supplied by Refcon A/S, Transportbuen 11, 4700 Næstved, Denmark. The thermal insulation layer may be a material such as Isobrick FI 139A, which is an Isolation stone that has a low thermal conduction, or approximately 0.19 W/m-K ASTM C 182 at 1000°C, supplied by Refcon A/S, Transportbuen 11, 4700 Næstved, Denmark. Alternative material for a thermal absorption layer may be a material such as Alocast H60, having a high thermal conductivity of 2.35 W/m-K at 800°C. Alternative material for a thermal absorption layer may be a material such as Alobrick TE600A, having a high thermal conductivity of 2.9 W/m-K at 800°C, supplied by Refcon A/S, Transportbuen 11, 4700 Næstved, Denmark. Alternative material for a thermal absorption layer may be Superwool 607 HT blanket, having a density of 128 kg/m³, having a low thermal conductivity at 0.23 W/m-K at 800°C, supplied by Thermal Ceramics, Tesby Road, Bromborough, Wirral CH32 3PH, United Kingdom.

[0065] The proximal end 8 may be made up of the following material in a direction from the inside to the outside, in a direction that is parallel to the central axis of the combustion chamber; 'The thermal absorption layer in form of Alocast H60 having a high thermal conductivity of 2.35 W/m-K at 800°C, a first thermal insulation layer in the form of Hasle BHII 1200 having a low thermal conductivity of 0.26 W/m-K at 800°C, and a second thermal insulation layer in the form of Rockwool Brandbatts having a low thermal conductivity of 0.034-0.116 W/m-K at between 10-400°C. The Alocast H60 is supplied by Refcon A/S, Transportbuen 11, 4700 Næstved, Denmark. The Hasle BHII 1200 is supplied by HASLE Refractories A/S, Almindingsvej 76, DK-3700 Roenne, DENMARK, and Rockwool Brandbatts is supplied by Rockwool A/S, Hovedgaden 501, 2640 Hødedusene, Denmark.

[0066] FIG. 2 shows a schematic diagram of a fluid fuel burning system 100 having a circulation arrangement 101 for feeding fuel into the fluid fuel burner 1. The fluid fuel is, as discussed in relations to FIG. 1, injected into the combustion compartment 2 via the injection nozzle 17, where the fuel is burnt in the combustion chamber 3 and the exhaust gasses exit the device via the exhaust chamber 4. The combustion chamber 3 is provided with an air inlet 16, which is connected to an air fan/compressor 24 that provides a flow of air to be introduced into the combustion compartment 2 to feed the fire with oxygen, and to provide an air flow through the longitudinal axis of the device 1, from the proximal end and to exit out of the open distal end 9 of the combustion compartment 2.

[0067] The circulation arrangement 101 may comprise a fuel tank 102 to hold the fluid fuel used to feed the fire inside the burning device 1, where the fuel tank has an inlet conduit 103 for introducing fluid into the tank, and an outlet conduit 104 for channelling fluid fuel out of the fuel tank 102. The circulation arrangement 101 may further comprise a driving arrangement, such as a pump 105, which may be used to drive the fuel out of the tank 102 and to feed the fuel under pressure inside the circulation arrangement 101. The pump 105 drives the fuel into a feeding conduit 106 that may be connected to a fuel line 107 that introduces fuel into the injection arrangement or a fuel inlet 23 of the burning device 1, and where the feeding conduit 106 is further connected to the inlet conduit 103 of the fuel tank, to allow the fuel that is not injected into the fuel inlet 23 to recirculate into the fuel tank 102.

[0068] The fuel injection into the nozzle 17 may be performed by introducing a pressure providing means, such as a compressor 25 that provides a constant pressure of air where the pressure may be in the vicinity of between 0.1-2 bar, or especially between 1.5 and 2 bar. This may mean that the fluid fuel being introduced into the fuel inlet 23 via the fuel line 107 has to exceed the pressure being provided using the compressor 25, or approximately 1.5-2 bar. If the pressure in the fuel line 107 is lower than the pressure inside the fuel inlet, the flow of fuel from the circulation arrangement is stopped, while should the pressure exceed, the pressure provided using the compressor 25, the fuel flow is commenced. This means that if the compressor 25 is providing pressure into the fuel inlet that is approximately 1.5 bar, the pressure inside the circulation arrangement has to exceed the pressure of the fuel inlet in order for fuel to flow into the nozzle.

[0069] When the fuel has passed the pressure providing means 25 in the fuel inlet 23, the fuel is forced into the fuel nozzle 17 under the pressure provided into the fuel inlet 23, i.e. if the circulation arrangement has a pressure that exceeds the pressure in the fuel inlet 23, the fuel may be injected into the compartment 2 at the same pressure as provided in the fuel inlet 23.

[0070] A first pressure measuring means 108 may be provided in the circulation arrangement 101, between the pump 105 and in order to monitor the pressure inside the circulation arrangement 101 and in order to control the pressure level inside the circulation arrangement 101, via a communication channel 111 between the first pressure measurement means 108 and a regulator valve 109, i.e. if the pressure inside the circulation arrangement 101 exceeds the pressure required to provide fuel flow into the device 1, the regulator valve 109 may be opened in order to reduce the pressure and thereby the fuel flow. The opposite may also be the case, where the pressure inside the circulation arrangement 101 is lower than what is required to provide fuel to the device 1, then the first pressure measuring means 108 may ensure that the regulator valve 109 is closed in order to build up the pressure necessary to provide the fuel flow into the device 1.

[0071] The exhaust chamber 4 of the combustion compartment 2 may be provided with an oxygen measurement means 26 that measures the oxygen content of the exhaust gasses, a second pressure measurement means 27, that measures the
pressure of the exhaust gases and inside the volume of the exhaust chamber 4, and a temperature measurement means 28, that may measure the temperature inside the exhaust chamber 4 and/or the burn chamber. The temperature measurement means may be used to control water injection into the circulation system, so that the water may be used to control the temperature inside the incineration chamber.

The oxygen measurement means 26, may have a communication channel 112 to control the release valve 109 that is arranged in the circulation arrangement 101. The purpose of the communications channel 112, is to allow the oxygen measurement means 26, a control input in order to control the pressure inside the circulation arrangement 101. This means, that the oxygen measurement means 26 may be equipped to reduce the pressure inside the circulation arrangement 101, should the oxygen level in the exhaust chamber 4 drop below a predefined value, in order to reduce the fuel flow into the fuel inlet 23 of the device 1. The drop in oxygen level in the exhaust gases may indicate that either too little air is being provided into the fluid/air mixture inside the combustion chamber 3, or that too much fuel is being provided into the fuel/air mixture inside the combustion chamber 3. The reduced fuel flow means that less fuel is burnt inside the combustion chamber 3, and the oxygen level in the exhaust gases is therefore increased. Should the oxygen level in the exhaust gases increase above a predefined level, the oxygen measurement means 26, may provide a control input to the circulation arrangement adapted to increase the pressure inside the arrangement 101, and thereby increase the fuel flow into the fuel inlet 23. An increase in the oxygen level may indicate that there is too much fuel in the fuel/air mixture compared to the amount of fuel being burnt, and/or that there is too little fuel compared to the air flow in the mixture.

An alternative method of controlling the oxygen level may be to allow the oxygen measurement means 26, to control the amount of air flow being provided by the air fan/compressor 24, into the combustion compartment 2 via the air inlet 16. Thus, when the oxygen level drops below a certain level, the oxygen measurement means 26, may increase the air flow via communication channel 113 to increase the amount of air in the fuel/air mixture inside the combustion chamber 3. The opposite could also be done where the oxygen level exceeds a predefined level, the air flow may be reduced to reduce the amount of air in the fuel/air mixture.

The second pressure measurement means 27 may be used to monitor the pressure of the exhaust gases, so if the pressure exceeds a predefined level, the pressure measurement means 27, may control the air fan/compressor 24 via communication channel 113, where the air flow into the compartment 2 may be reduced in order to reduce the amount of fuel being burned and to reduce the pressure induced by the air fan/compressor 24. The opposite may also be the case, where a drop in pressure below a predefined level may instruct the air fan/compressor 24 to increase the air flow into the compartment 2, and thereby increase the pressure inside the compartment 2.

The variations in air flow inside the chamber 2 provided by the air fan/compressor may be regulated by the oxygen measurement means 26, so that any change in air flow will be compensated by the injection of fuel into the combustion chamber 3 due to variations in oxygen levels measured by the oxygen measurement means 26, in order to maintain an optimum fuel/air mixture, as discussed earlier.

The oxygen measurement means 26 and the pressure measurement means 27 may therefore provide a self-regulating mechanism between the air flow and fuel flow into the combustion compartment, so that any variations in pressure and/or oxygen content are regulated automatically by the measurement means 26, 27 via the communication channels 112, 113 to the air fan/compressor 24 and the regulator valve 109 and the fluid inlet valve 110.

FIG. 3 shows a schematic diagram of a process of a water gas shift reaction that may be performed inside the fuel burning device 201, in accordance with the invention. In FIG. 3, a fuel drop 202 that comprises a hydrocarbon fuel and water is fed into a fuel nozzle 203. The fuel nozzle 203 is arranged at a proximal end 204 of an combustion chamber 205, where the inner wall 206 of the combustion chamber 205 is made of a heat absorbent material, so that heat 207 may radiate from the inner surface 208 of the inner wall 206.

The fuel nozzle 203, is arranged in an opening 209 in the distal end 204 of the combustion chamber 205, where air is injected using an air source 210, in parallel with the fuel nozzle 203 into the combustion chamber 205. Also, close to the opening, there may be a means of ignition 211 in order to ignite the fuel inside the combustion chamber, when needed.

When the fuel drop 202 has entered the fuel nozzle 203, the fuel drop 202 becomes aerated, where the single fuel drop 202 is broken up into smaller particles 212. The smaller fuel particles 212 comprise an organic part 214 (hydrocarbon droplet) having small particles of water (H2O) 213 suspended inside the organic part 214.

FIG. 3b shows when the fuel particle has entered the combustion chamber 205 and as the combustion chamber has a high temperature, the heat 207, which emanates from the inner surface 208 and the inner volume of the combustion chamber 205, rapidly heats up the fuel particle 212. The rapidly heated fuel particle 212 causes the water particles 213 to explosively expand from liquid state to gaseous state, where the volume increase of the water is approximately 1700 fold, as may be seen in FIG. 3c.

The explosive expansion of the water particles 215 causes the organic material to explode into a number of small organic particles 215, which are thrown radially away from the centre of the expansion 215, causing the organic material 216 to disperse inside the combustion chamber 205.

When the organic material 216 has dispersed inside the combustion chamber 205, the surface area of the organic material has been increased significantly, compared to a single droplet of organic material, i.e. when one large droplet is dispersed into smaller particles, the total surface area of organic material increases significantly. As shown in FIG. 3b, a single organic particle 216, which was earlier a part of the larger fuel particle 212, begins to vaporize on the surface area creating a strong reducing condition for the following water shift reaction, as shown by arrows 217, and the organic particle, which comprises carbon, may easily be oxidised (incinerated), where the oxidized particle releases energy in the form of heat.

A simplified chemical reaction for the first part of the water gas synthesis/water shift reaction is as follows:

\[ \text{C}_2\text{H}_6\text{O} \rightarrow \text{CO}_2 + \text{H}_2 \]

Where the carbon atom (C) and the water particle is provided by the fuel particle 212, shown in FIG. 3. The second
part of the water gas synthesis/water shift reaction is as follows:

\[ \text{CO} + \text{H}_2 \text{O} \rightarrow \text{H}_2 \text{O} + \text{CO}_2 \]

[0085] Where the oxidation of the carbon releases energy in the form of heat, and the complete reaction is exothermic.

[0086] Thus, using the water gas shift reaction inside the fuel burning device it is possible to separate the water molecules from the organic molecules in order to yield an effective oxidation of fuel, especially where the water content of the fuel is high, such as a fuel mixture having a low calorific value, such as waste material.

[0087] FIG. 4 shows a cross sectional view of a device 1 for burning fluid fuel taken along the axis IV-IV in FIG. 1, where the central axis of the device 1 is perpendicular to the axis IV-IV. The combustion compartment 2 is surrounded, in this view, with a thermal absorbent layer 10, which is adapted to absorb the thermal energy generated inside the combustion compartment 2, when fluid fuel is being burnt. The thermal absorbent layer 10 is furthermore surrounded by a thermal insulation layer 11, which abuts the thermal absorbent layer, ensuring that the transfer of thermal energy in the thermal absorbent layer 10 and/or the combustion compartment 2, is reduced in a direction from the central axis of the combustion compartment 2 towards the outside of the device, as indicated by arrow 13. The thermal insulation layer 11 is surrounded by a side wall 21 of the device 1, which may be seen as the outer shell of the device.

[0088] During operation of the fluid burning device 1, the fuel is injected into the combustion chamber 3 via the aeration nozzle 17. The fuel combusts when it comes into contact with the earlier burnt fuel, or when the initial ignition is obtained by the ignition element 20. The temperature \(T_1\) of the ignited fuel will initially be significantly higher than the temperature \(T_2\) of the thermal absorbent layer 10, \(T_1 \gg T_2\), during the startup of the device 1. Thus, in the initial startup period of the device 1, the heat from the combustion chamber will be absorbed into the thermally absorbent layer 10. The thermal energy absorbed into the thermal absorbent layer 10 raises the temperature \(T_2\) of the thermally absorbent layer 10, up to a point where a thermal equilibrium is achieved, where the temperature inside the combustion chamber 3 is substantially equal to the temperature of the thermally absorbent layer 10, \(T_2 \approx T_2\). The thermal insulation layer 11 ensures that the thermal energy absorbed inside the thermally absorbent layer 10, is maintained inside the thermally absorbent layer 10, and reduces the heat transfer from the thermally absorbent layer 10 in a direction away from the central axis of the device 1 and towards the outside of the device.

[0089] When the thermal equilibrium is achieved between the combustion chamber 3 and the absorbent layer 10, the thermal energy within the combustion chamber and the thermally absorbent layer is substantially uniform where the thermal energy within the absorbent layer will radiate into the combustion chamber and vice versa, in order to maintain a thermal equilibrium between the two bodies (combustion compartment 3 and absorbent layer 10).

[0090] Due to the fact that the thermal insulation layer 11 has a predefined thermal conductivity, the thermal energy inside the absorbent layer 10 will be transferred into the thermal insulation layer, which will reduce the energy absorbed in the absorbent layer 10. However, as the thermal conductivity between the absorbent layer 10 and the thermal insulation layer 11 is constant, the thermal dissipation between the two layers is predictable, and an example of a thermal conductivity between the two layers may be seen in FIG. 5a.

[0091] When the thermal equilibrium is reached between the absorbent layer 10 and the combustion chamber 3, and the absorbent layer radiates thermal energy into the chamber 3 as well as absorbing thermal energy from the combustion chamber 3, it is ensured that there are no cool zones inside the combustion chamber, and especially in areas that are in close proximity to the inner surface of the absorbent layer. Thus, the fuel fed into the combustion chamber 3 will combust at a substantially level temperature inside the combustion chamber, regardless of the radial position inside the chamber. Thus, the aerated fuel particles fed into the chamber 3 will combust at the same speed and rate everywhere inside the chamber 3. Thus, it is ensured that if any fuel particles are jetted into the chamber in a direction towards the inner surface of the absorbent layer, the surface area of the absorbent layer will be at a similar temperature as the temperature inside the central areas of the chamber, and thereby ensure that all particles will be combusted up to the same degree everywhere and ensure a clean combustion process inside the chamber 3. This results in a combustion process where substantially all hydrocarbons in the fluid fuel are burnt.

[0092] Should the inner wall of the combustion chamber be of a refractory material or a thermally insulating material, and not an absorbent material, such as shown is in the prior art, the temperature of the inner surface of the combustion chamber would be lower than inside the combustion chamber, and substantially no thermal energy would be radiated back into the combustion chamber. Thus, the particles that are ignited close to the inner walls of the refractory or insulation material would burn/combust at a lower temperature than in central areas of the combustion chamber and such combustion would leave unburnt hydrocarbons, resulting in an unclean combustion exhaust.

[0093] In one example of a device in accordance with the invention, the outer diameter of the side walls 21 of the device 1, may be 2200 mm, where the side wall 21 has a thickness of 5 mm, and the insulation layer 11 has a thickness of 114 mm and the absorption layer 10 has a thickness of 114 mm, so that the inner diameter of combustion chamber 3 is approximately 1744 mm. The length of the combustion chamber (parallel to the central axis) may be approximately 4500 mm, and the support rings 22 (FIG. 1) are spaced at approximately 500 mm apart, and are 12 mm in width and have a height of 60 mm, resulting in an outer diameter at the support rings at 2320 mm.

[0094] FIG. 5a-c shows temperature graphs, where the vertical axis shows temperature, and the horizontal axis shows material thickness. The graphs represent temperature measurements of examples of at least one thermal absorbent layer and one thermal insulation layer arranged in accordance with the invention, in a controlled environment. The temperature measurements are made at a substantially thermal steady state, where the temperature inside the combustion chamber is measured at 1100°C, and the thermal absorption layer and the thermal insulation layer have reached their steady state temperature. The temperature graphs represent the layered structure of the walls of the fluid burning device 1 is represented from left to right, representing the layered structure in a direction from the central axis and towards the outside. I.e.
the leftmost layer in the graph is the innermost layer of the device, and the layer to the extreme right of the graph, is the outermost layer of the device.

FIG. 5 shows a second example of a thermal absorbent layer, a thermal insulation layer and a steel side wall, where the layers surround a combustion chamber 3, as shown in FIG. 1 and FIG. 4. The example shows a thermal absorption layer 51 that is a 114 mm Refcon-ALobrick TE 200A, a thermal insulation layer that is a 114 mm Refcon-Isobrick FL 139A, and an outer steel wall 53 that is a 5 mm ST 37 steel wall comprising the outer structure of the device. In this example, the innermost surface of the absorption layer 51 is measured at 1100°C, which corresponds to the temperature inside the combustion chamber. The temperature drops to 1000°C at the interface between the absorption layer 51 and the insulation layer 52, which is a drop of approximately 91 degrees across the thickness of the absorption layer 51. The temperature is measured at 83°C at the interface between the insulation layer 52 and the outer steel wall 53, which is a temperature drop of 926°C across the thickness of the insulation layer 52. The temperature is measured at 83°C at the outer surface of the outer steel wall 53, which means that the temperature drop across the thickness of the outer steel wall 53 is negligible.

FIG. 5b shows a second example of a thermal absorbent layer 54, a thermal insulation layer 55 and a steel wall 56, where the layers represent an example of a layered structure of a transitional chamber 4 having a conical shape, as shown in FIG. 1. The example shows a thermal absorption layer 54 that is a 100 mm Refcon-Alocast H60, a thermal insulation layer 55 that is a 50 mm Refcon-Superwool 607 HT, and an outer steel wall 556 that is a 5 mm ST 37 steel wall, comprising the outer structure of the device. In this example the innermost surface of the absorption layer 54 is measured at 1100°C, which corresponds to the temperature inside the combustion chamber. The temperature drops to 955°C at the interface between the absorption layer 54 and the insulation layer 55, which is a drop of approximately 145 degrees across the thickness of the absorption layer 54. The temperature is measured at 129°C at the interface between the insulation layer 55 and the outer steel wall 56, which is a temperature drop of 826°C across the thickness of the insulation layer 55. The temperature is measured at 129°C at the outer surface of the outer steel wall 56, which means that the temperature drop across the thickness of the outer steel wall 56 is negligible.

FIG. 5c shows a second example of a thermal absorbent layer 57, a first thermal insulation layer 58, a second thermal insulation layer 59 and a steel wall 60, where the layers represent an example of a layered structure of a closed proximal end 6 of the combustion chamber 3 transitional chamber 4 having a conical shape, as shown in FIG. 1. The example shows a thermal absorption layer 57 that is a 230 mm Refcon-Alocast H60, a first thermal insulation layer 58 that is a 110 mm Refcon-BHI 1200, a second thermal insulation layer 59 that is a 50 mm Refcon-Rockwool Brandblatts, and an outer steel wall 60 that is a 5 mm ST 37 steel wall comprising the outer end structure of the device. In this example the innermost surface of the absorption layer 57 is measured at 1100°C, which corresponds to the temperature inside the combustion chamber. The temperature drops to 963°C at the interface between the absorption layer 57 and the first insulation layer 58, which is a drop of approximately 137°C across the thickness of the absorption layer 57. The temperature is measured at 560°C at the interface between the first insulation layer 58 and second insulation layer 59, which is a temperature drop of 403°C across the thickness of the second insulation layer 58. The temperature is measured at 75°C at the interface between the second insulation layer 59 and the outer steel wall 60, which is a temperature drop of 485°C across the thickness of the second insulation layer 59. The temperature is measured at 75°C at the outer surface of the outer steel wall 60, which means that the temperature drop across the thickness of the outer steel wall 60 is negligible.

Within the meaning of the present invention, the term thermal energy has the same meaning as heat.

1. A fluid fuel burning device, comprising:
an elongated combustion compartment comprising side walls having an outer surface and an inner surface defining the radial periphery of the combustion compartment having a central axis extending from a proximal end to a distal end of the compartment in the longitudinal direction, where distal end is open allowing fluid communication from inside the combustion compartment and out of the compartment; airflow means for providing a current of air in a direction from the proximal end of the combustion compartment and towards the distal end in a direction parallel to the central axis of the compartment; a fuel nozzle for introduction of fluid fuel inside the combustion compartment, fuel feeding means for feeding fluid fuel to the fuel nozzle, pressure providing means for applying pressure to the fluid fuel fed via the fuel feeding means; a thermal insulation layer arranged radially between the central axis of the combustion compartment and the side walls of the compartment, reducing the heat transfer in a direction from the central axis of the combustion compartment towards the side walls; characterized in that the fluid fuel burning device further comprises
a thermal absorbent layer arranged radially between the central axis of the combustion compartment and the insulation layer, allowing thermal energy generated within the combustion compartment to be absorbed and radiated back into the combustion compartment in a direction towards the central axis where thermal equilibrium has been reached between the combustion compartment and the thermal absorbent layer.

2. A device according to claim 1, wherein the pressure provided means are configured to apply a pressure of between 1-5 bar, or more specifically between 1.1 and 3 bar or more specifically between 1.5-2 bar.

3. A device according to any of the preceding claims, wherein the elongated combustion compartment has an inner surface area having a first cross sectional diameter and a second inner surface area that has a second cross sectional diameter, where the first cross sectional diameter is smaller than the second cross sectional diameter.

4. A device according to any of the preceding claims, wherein the elongated combustion compartment has a first right circular cylindrical volume having a first cross sectional diameter and a second right circular cylindrical volume hav-
ing a second first cross sectional diameter that is smaller than the first cross sectional diameter.

5. A device according to any of the preceding claims, wherein the inner end proximal end section of the combustion compartment comprises the fuel nozzle and an outlet for the fan ensuring that the air supply envelops the fuel nozzle for feeding oxygen in a direction parallel to the longitudinal axis of the compartment.

6. A device according to any of the preceding claims, wherein the fuel feeding means comprise a circulating fuel arrangement, the arrangement comprising a fuel tank, an output conduit from fuel tank, an input conduit into fuel tank, a driving arrangement for circulating the fluid, a regulator valve for regulating the pressure inside the circulating fuel arrangement, and a fluid input means for incrementing the amount of fluid inside the circulating fuel arrangement.

7. A device according to any of the preceding claims, wherein the device comprises an oxygen measuring means and/or a pressure measuring means arranged to measure the oxygen and/or pressure of the exhaust gas of the device.

8. A device according to any of the preceding claims, wherein the pressure and/or the oxygen measuring means has at least part control of the regulator valve.

9. A device according to any of the preceding claims, wherein the pressure and/or the oxygen measuring means controls the magnitude of air provided by the air flow means.

10. A device according to any of the preceding claims, wherein the fluid input comprises a water input means for introducing liquid water into the closed circulating fuel arrangement.

11. A device according to any of the preceding claims, wherein the thermal absorption layer is a layer of a material that has a high thermal conductivity, or approximately between 1.2-3.0 W/m-K ASTM C 182 at 800° C., more specifically the thermal conductivity may be between 1.3 and 2.5 W/m-K ASTM C 182 at 800° C., even more specifically between 1.5 and 2.4 W/m-K ASTM C 182 at 800° C.

12. A device according to any of the preceding claims, wherein the thermal insulation layer is a layer of a material that has a low thermal conductivity, or approximately between 0.1-0.5 W/m-K ASTM C 182 at 800° C., more specifically the thermal conductivity may be between 0.1 and 0.35 W/m-K ASTM C 182 at 800° C., even more specifically between 0.15 and 0.24 W/m-K ASTM C 182 at 800° C.

13. A method of regulating a fluid fuel flow in a device for burning fluid fuel, comprising the steps of:

   providing an elongated combustion compartment having a proximal closed end and a distal open end,
   providing an air flow in a direction from the proximal closed end to the distal open end,
   providing an aerated fuel flow inside the elongated combustion compartment,
   igniting the aerated fuel inside the elongated combustion compartment,
   measuring the oxygen content of the exhaust gases for the apparatus,
   adjusting the air flow based on the oxygen content and/or the pressure of the exhaust gases,
   adjusting the fuel flow based on the oxygen content and/or the pressure of the exhaust gases.

14. A method according to claim 13, wherein the air flow is increased or decreased if the oxygen content drops below or exceeds a first predefined percentage oxygen level, respectively.

15. A method according to any of claims 13-14, wherein the method further comprises a step of measuring the pressure of the of the exhaust gases for the apparatus.

16. A method according to any of claims 13-15, wherein the air flow is decreased if the pressure of the exhaust gases exceeds a first predefined pressure level.

17. A method according to any of claims 13-16, wherein the air flow is increased if the pressure of the exhaust gases drops below a predefined pressure level.

* * * * *