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[54] WATER HEATER HAVING FLUIDIZED BED COMBUSTION AND HEAT EXCHANGE REGION

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[52] **U.S. Cl.** ..... **122/4 D**, 110/28 J

[51] **Int. Cl.** **F22b 1/02**

[58] **Field of Search** ..... 122/4 D; 110/28 J; 165/105

[56] **References Cited**

UNITED STATES PATENTS

2,610,842	9/1952	Schoenmakers et al.	122/4 X
2,976,853	3/1961	Hunter et al.	122/4
3,397,657	8/1968	Tada	110/28 X
2,459,836	1/1949	Murphree	122/4 X
2,729,428	1/1956	Milmore	122/4 X
3,565,022	2/1971	Bishop	122/4 X

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[57] **ABSTRACT**

Water is heated to an elevated temperature or steam is produced, by passing water through heating coils which are embedded in a fluidized bed of inert particles. The heat for the system is produced by combustion of a material such as propane, methane or the like in a lower zone of the fluidized bed. The combustion is stabilized by intermixing small particles and large particles in the lower zone. The large particles are not fluidized but are merely suspended in the upflowing fluid, and the small particles are fluidized in the interstices of the large, relatively stationary particles.

12 Claims, 2 Drawing Figures

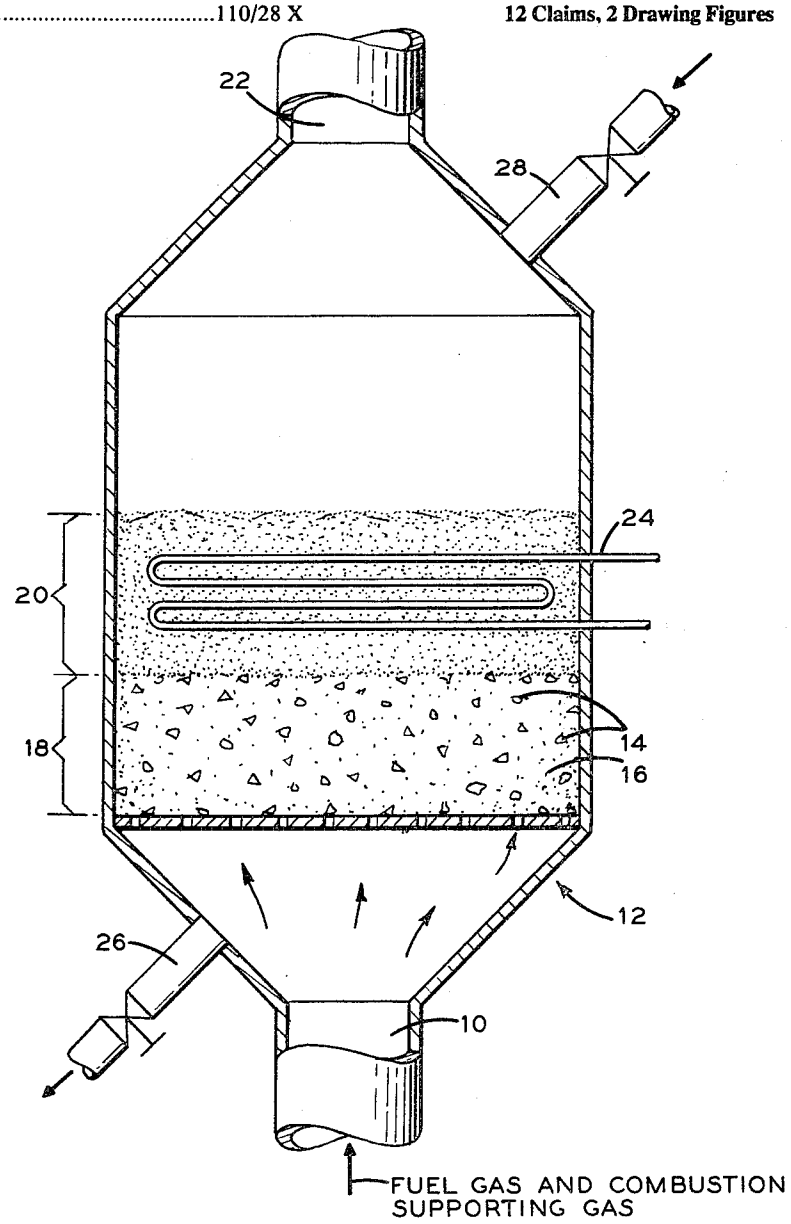


FIG. 1

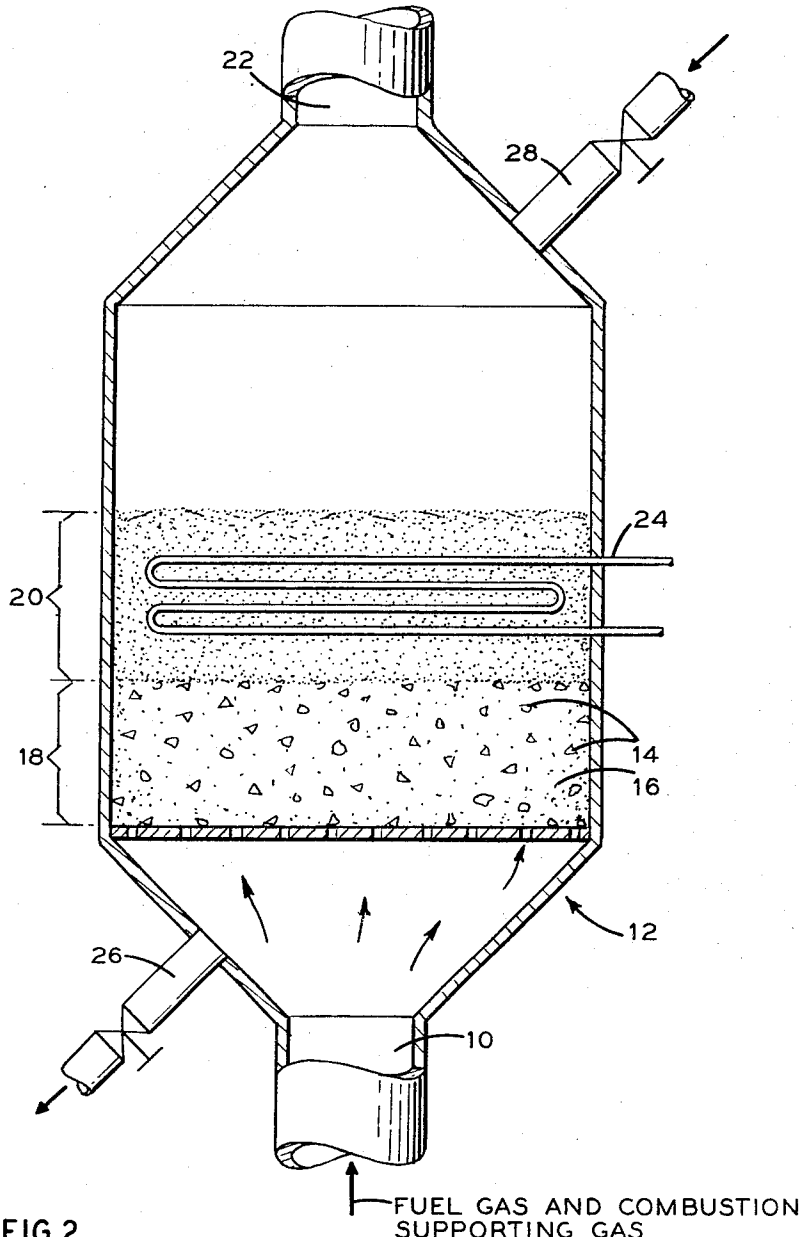
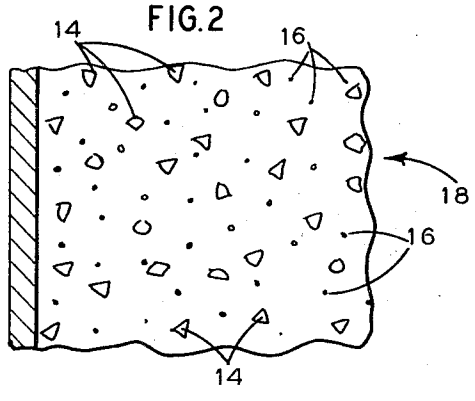


FIG. 2



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WATER HEATER HAVING FLUIDIZED BED COMBUSTION AND HEAT EXCHANGE REGION

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to fluid heaters or boilers of the type in which heat transfer between the combustible material and the fluid is achieved by fluidized, inert particles. The invention relates more particularly to the heating of fluidized particles by combustion in a heating zone and the transfer of the heat to a fluid in a heat transfer zone.

2. Description of the Prior Art

In the conventional design of an industrial boiler, combustion occurs within a large fire tube and the water is circulated outside the tube where the boiling occurs. The combustion products are cooled in the return tube bank before being discharged to the atmosphere.

Radiation is the controlling mechanism of heat transfer from the combustion fire tube to the surrounding water and forced convection is the dominant mechanism of heat transfer from the combustion products in the return tube to the surrounding boiling water.

In residential type gas fired boilers, gas is mixed with an excess of air to produce almost 100 percent combustion and the hot gases are passed around and/or between water tubes and then through the flue pipe to the atmosphere.

Current trends have been toward systems, which permit the size of the boiler to be reduced and which improve the heat transfer rate to the water so that a low level of heat is sent by the boiler into the room in which the boiler is housed. Also, in tankless hot water heaters, that is, heaters which do not have a tank for storing household hot water "instantaneous" heating of water in coils is required. Rapid heat transfer is essential because of the high demand level of appliances such as dishwashers and clothes washers which rapidly use large quantities of hot water, and which may be used simultaneously.

SUMMARY OF THE INVENTION

It has now been found that the requirements of hydronic heaters and commercial boiler systems can be fulfilled through the use of a fluidized bed boiler system.

The boiler or heater includes a housing having a combustible gas and a combustion supporting gas inlet at its lower end and a flue gas outlet at its upper end. A fluidized bed is supported within the housing and provided with a lower fluidized zone in which combustion takes place, and an upper fluidized zone in which heat transfer takes place. The combustion zone is provided with large relatively stationary inert particles and relatively small particles which are fluidized in the interstices of the large, relatively stationary particles. The heat transfer zone is provided with water tubes which carry water through the heat transfer zone of the fluidized bed thereby transferring heat from the fluidized bed to the water.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects, features and advantages of the present invention will become apparent as the description proceeds, particularly when taken together with the accompanying drawings, wherein like reference numerals indicate similar parts throughout the several drawings, and wherein:

FIG. 1 is a schematic representation of a heating system in accordance with the present invention; and

FIG. 2 is a schematic representation of an enlarged portion of the fluidized bed of the heating system of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is well known that heat transfer from combustion gases to boiler walls is the limiting factor in the thermal design of forced draft boilers and water heaters. One method for improvement of this heat transfer rate is through increased turbulence in the gas phase. An order-of-magnitude increase in the heat transfer rate is achieved if combustion is allowed to proceed within a bed of inert material (such as sand) at velocities which cause the bed to become fluidized (e.g., at gas velocities which cause the solid particles to be buoyed up, thus separating). The increase in heat transfer rate is due primarily to the high degree of turbulence in the fluidized bed, and this improvement is reflected in an order-of-magnitude reduction in the amount of heat transfer surface area required per unit of energy transferred to the water. In addition, the high degree of gas-solid contacting results in a nearly isothermal bed temperature, thus minimizing local "hotspots," uneven stressing of the boiler tubes, and burnout tendencies.

The solid heat exchange material, which is generally used in these processes, is of the granular particle size and generally in the neighborhood of 0.001 inch in diameter to about 0.10 inch in diameter, although particles of about roughly 46 mesh (0.0014) inch in diameter are generally preferred. The particles are generally substantially inert being utilized almost exclusively as a heat-carrying medium. The particles are formed of various types of refractory material which will withstand very high temperatures without fracturing or crumbling in the continuous moving bed process. Various metal alloys have been used as well as ceramic material. Other inert material, such as alumina, zirconia or mullite, may be used as the granular particles in this process. Generally, the carbides, oxides and nitrides of silicon, aluminum, hafnium and other refractory materials can be used.

Generally, the principles of combustion in fluidized beds is disclosed in U.S. Pat. No. 2,976,853.

Basically, as shown in FIG. **1**, a combustible gas and a combustion supporting gas, are fed under sufficient pressure to fluidize a bed of particles, and are fed through an inlet **10** to a heater **12**. While it is possible to use various gases, and even liquid combustibles, if desired, in residential applications, natural gas would most commonly be employed. Carbon monoxide, hydrogen, butane, propane, are illustrative of gases which can be used. The combustion supporting gas is most commonly air, although other oxygen carriers can be used.

The combustion occurs in direct contact with the solid particles **14** and **16** in the combustion zone **18**.

As shown in FIG. **2**, the combustion zone is made up of large particles **14**, which are relatively stationary and small particles **16**, which are fluidized in the interstices between the large particles. The large particles are on the order of one inch in diameter as compared to the small particles which are less than one tenth of an inch in diameter.

The combustion products are withdrawn through the conduit **22** at the top of the heater **12**. The combustion which takes place in the combustion zone **18**, rapidly heats the inert solid particles to a temperature, which in the case of natural gas, would be about 400° F.

The large particles **14** do not migrate from the combustion region **18**, but the small particles **16**, are fluidized and flow freely between the upper heat transfer zone **20** and the lower combustion zone **18**.

A cold bed of sand particles, can be heated to equilibrium or operating temperature in approximately 15 minutes, depending upon fluid pressures employed, particle size, etc.

The heat of combustion is transferred to water by means of tubes **24**, which pass through the heat transfer zone **20**. In a steel hydronic boiler 15 sq. ft. of surface area is typically required to transfer a heat flux of 100,000 B.t.u./hr. In a fluidized bed boiler the same amount of heat can be transferred by 5 square of heat transfer surface area, using an operating temperature of 400° F. and spherical sand particles of 0.01 inch diameter.

As compared to a conventional boiler system which typically requires 232 sq. ft. of heat transfer surface area to transfer $3,422 \times 10^3$ B.t.u./hr. (or 147,400 B.t.u./(hr.) (ft.)^2) to transfer the same amount of heat in a fluidized bed boiler unit, 128 sq. ft. is required when using 0.01-inch particles, or 22 sq. ft. when using 0.001-inch particles. The net saving in heat transfer surface area is 55 percent and 92 percent respectively, for 0.01-inch and 0.001-inch particles.

The turbulent motion of the particles is the main cause of the high heat transfer coefficient between the particles and the interior heat transfer surface of the bed. An equivalent high degree of turbulence at the surface tube is not possible in the design of a conventional boiler system, because the heat is transferred via the boundary layer to the heat transfer surface tube in a forced or natural convection based boiler design in contrast to the direct contact by the particles on the surface of a tube in a fluidized bed boiler. The direct contact on the surface of tube in a fluidized bed boiler design is more effective than the boundary layer gas phase heat transfer in a natural or forced convection boiler design.

The pressure drop through the fluidized bed is typically greater than that in a conventional boiler working on radiation or convection heat transfers, therefore requiring greater air and fuel supply pressures in fluidized bed boilers than in conventional boilers. This factor, which makes operating costs greater in fluidized units than in conventional units is minimized by using the large relatively stationary particles **14**. Thus, the large particles not only serve to stabilize the combustion, but also to reduce the pressure drop through the system.

The overall temperature level of the bed remains constant, under steady state operating conditions. The temperature level of the bed under dynamic conditions depends on the rate at which heat is extracted from the system by the heat exchanger surfaces **24** placed inside the fluidized bed system **20**. If the rate of heat transfer from the bed to the interior heat transfer surface is higher than the heat input to the bed by the hot fluidizing gases, then the bed is said to be thermally unstable. The high heat output from the system and the low heat input to the bed particles by the fluidizing gases will gradually lower the operating temperature of the bed and either extinguish the bed or at the least, decrease the overall magnitude of the temperature driving force. The presence of nonfluidized, relatively stationary large particles, in the combustion zone, serves to maintain the combustion zone at a relatively constant, or stable temperature.

Due to the high gas phase heat transfer coefficient obtained in the fluidized bed and consequent reduction in heat transfer surface area, the fixed cost of a hydronic heater, or high heat flux boiler can be reduced very substantially.

Furthermore, the physical size of the unit can be dramatically reduced by virtue of the decreased heat transfer surface area requirement.

In residential-type hydronic boilers using tankless hot water heaters, the high heat transfer rate of fluidized beds enables greatly improved water supply capabilities.

As a further advantage, the high heat capacity of the solid inert particles in the bed serves to retain heat for long periods of time after the fuel and air supply to the bed has been cut off, thereby enabling the system to rapidly supply heat, even after long periods of not being heated.

The life of the large (one inch) particles **14**, can be expected to be typically virtually unlimited, because wearing down of the particle from, for example, a diameter of somewhat greater than 1 inch could take many years, but would not affect the operation of the system.

The life of the small fluidized particle **14**, will vary depending upon abrasion resistance, particle size and shape, operating temperatures and the like. Particles of sand 0.001 inch in diameter could last in a residential hydronic boiler, for a period well in excess of 1 year. In any event, replacement of the excessively pulverized sand simply consists of opening a sand removal conduit **26**, located at the bottom of the heater **12**, and replenishing the sand supply through an access **28** provided at the top of the boiler.

The extremely low cost of sand makes the factor of useful sand life one of convenience rather than one of economics. The process according to the invention is illustrated by the following example:

The fluidized bed which was employed was provided with an outer water jacket throughout its entire length. The fluidized bed was made up of large particles and sand particles in the −30 to +40 mesh size range.

Propane was fed to the bed at a pressure of 24 p.s.i.g. and air fed at a pressure of 14 p.s.i.g. Water was pumped through the coils at a rate of 1.3 gallons per minute. The pressure drop through the bed was over 4 p.s.i.

Temperature reading at various bed levels were taken by means of thermocouples. After about 15 minutes, the bed reached an equilibrium condition and temperatures were relatively constant. Temperatures were observed at various bed heights, as follows: at 0 inches—534° F., at 2.5 inches—711° F., at 4.5 inches—725° F., at 6 inches—1,020° F., at 7 inches—1,150° F., at 8 inches—1,020° F., at 18.5 inches—987° F., at 20.5 inches—998° F.

The water temperature at the inlet was 67° F. and at the outlet 111° F.

By way of contrast, 120-mesh particles with a fluidized height of three to three and one half inches and an unfluidized height of 1½ inches were supported on a distributor plate. Propane was fed to the bed and a temperature of 298° F. was obtained. Repeated efforts were made under steady combustion conditions which failed to raise the bed temperature above 298° F. With a greater bed height a temperature of 398° F. was obtained but attempts to raise the bed temperature to a higher level were unsuccessful.

Although the invention has been described in its preferred forms with a certain degree of particularlity, it is understood that the present disclosure of the preferred forms has been made only by way of example, and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention.

What is claimed is:

1. A heater comprising:

a combustion zone which includes a substantially stationary porous matrix defining a tortuous passage system, and fluidizable particles trapped in the matrix system for multiple collisions with each other and the molecules in the flowing combustibles; and

a fluidized bed receiving hot gases issuing from the combustion zone, and a heat exchanger immersed in the fluidized bed for accepting heat from the fluidized particles by scouring effects on the heat exchanger walls.

2. The heater of claim **1** wherein the substantially porous matrix is formed by discrete particles sized sufficiently large to remain unfluidized.

3. The heater of claim **2** wherein the matrix-forming particles have diameters greater than 0.5 inch, and the fluidizable particles have diameters less than 0.1 inch.

4. The heater of claim **1** wherein the individual matrix-forming particles are of sufficient mass and heat-retaining character as to maintain relatively high temperatures in the combustion zone.

5. The heater of claim **1** wherein the matrix-forming particles are configured and sized so as to have limited contact with one another, whereby the matrix has a substantial heat-retaining character.

6. A heater comprising:

a combustion bed which includes relatively large nonfluidized particles and relatively small fluidized particles in the interstices between the large particles;

a fluidized bed receiving gases issuing from the combustion bed; and

a heat exchanger immersed in the fluidized bed.

7. The heater of claim **6** wherein the fluidized bed is formed directly above the combustion bed; said fluidized bed comprising fluidizable particles of the same size and mass as the fluidizable particles in the combustion bed.

8. The heater of claim **7** wherein the fluidized bed is contiguous to the combustion bed whereby fluidizable particles are enabled to circulate between the two beds.

9. The heater of claim **6** wherein the combustion bed is of sufficient depth as to maintain a substantial temperature increase between the inlet face and its outlet face.

10. The heater of claim 6 wherein the combustion bed is of sufficient depth that the gas temperature rises appreciably as the gas moves into the bed interior and then levels off as the gas nears the outlet face of the combustion bed.

11. A heater comprising:

a first combustion bed containing fluidizable particles buffeted by the flowing gases;

a second heat transfer bed containing fluidizable particles; and

a heat exchanger immersed in the heat transfer bed;

said combustion bed being thermally isolated from the heat transfer bed so that combustion temperatures are maintained.

12. The heater of claim 11 wherein the thermal isolation is achieved by structuring the combustion bed as a number of separated compartments, each containing fluidizable particles.

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