

[54] **FLUIDIZED BED HEAT EXCHANGER**

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

[56] **References Cited**

UNITED STATES PATENTS

2,818,049	12/1957	Blaskowski	122/4 X
2,842,102	7/1958	Blaskowski	122/4

2,983,259	5/1961	Wittke	122/4
3,119,378	1/1964	Marshall	122/4
3,431,892	3/1969	Godel	122/4
3,648,666	3/1972	Foldes et al.	122/4
3,659,559	5/1972	Foldes et al.	122/4
3,736,908	6/1973	Ehrlich et al.	122/4

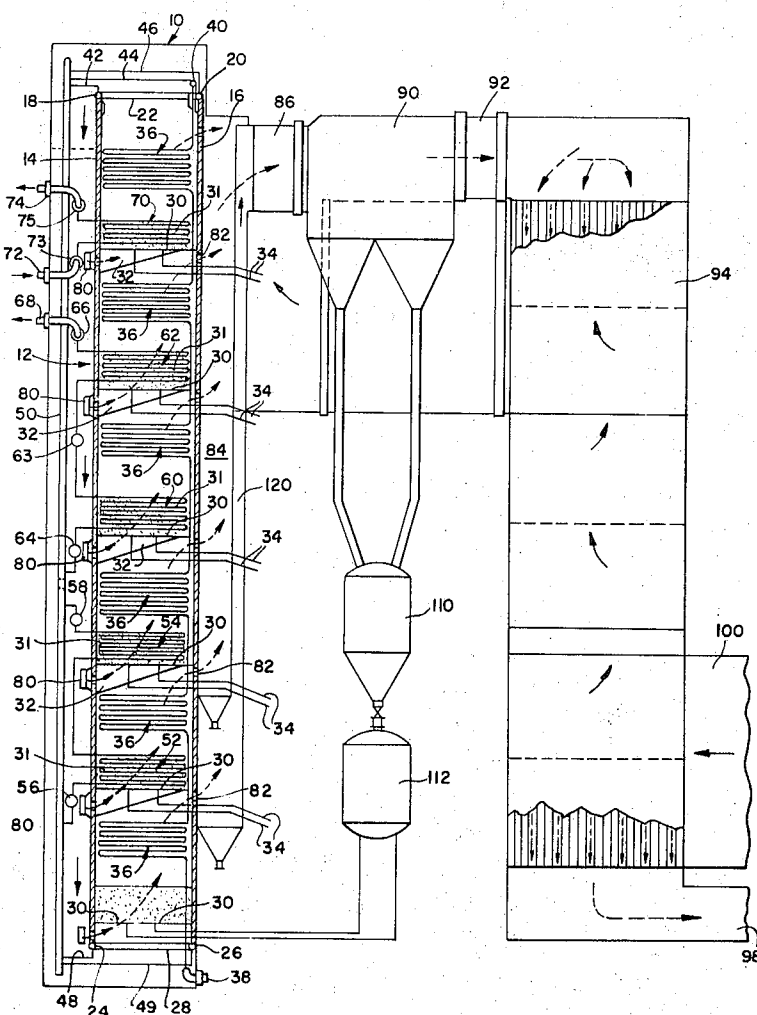
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[57]

ABSTRACT

A vapor generator in which a plurality of vertically stacked beds of particulate material containing a solid fuel are disposed in a housing. Air is passed through each of the fuel beds to promote the combustion of the fuel and maintain the beds at predetermined temperatures while a heat exchange medium is circulated in a heat exchange relation to the beds.

9 Claims, 2 Drawing Figures



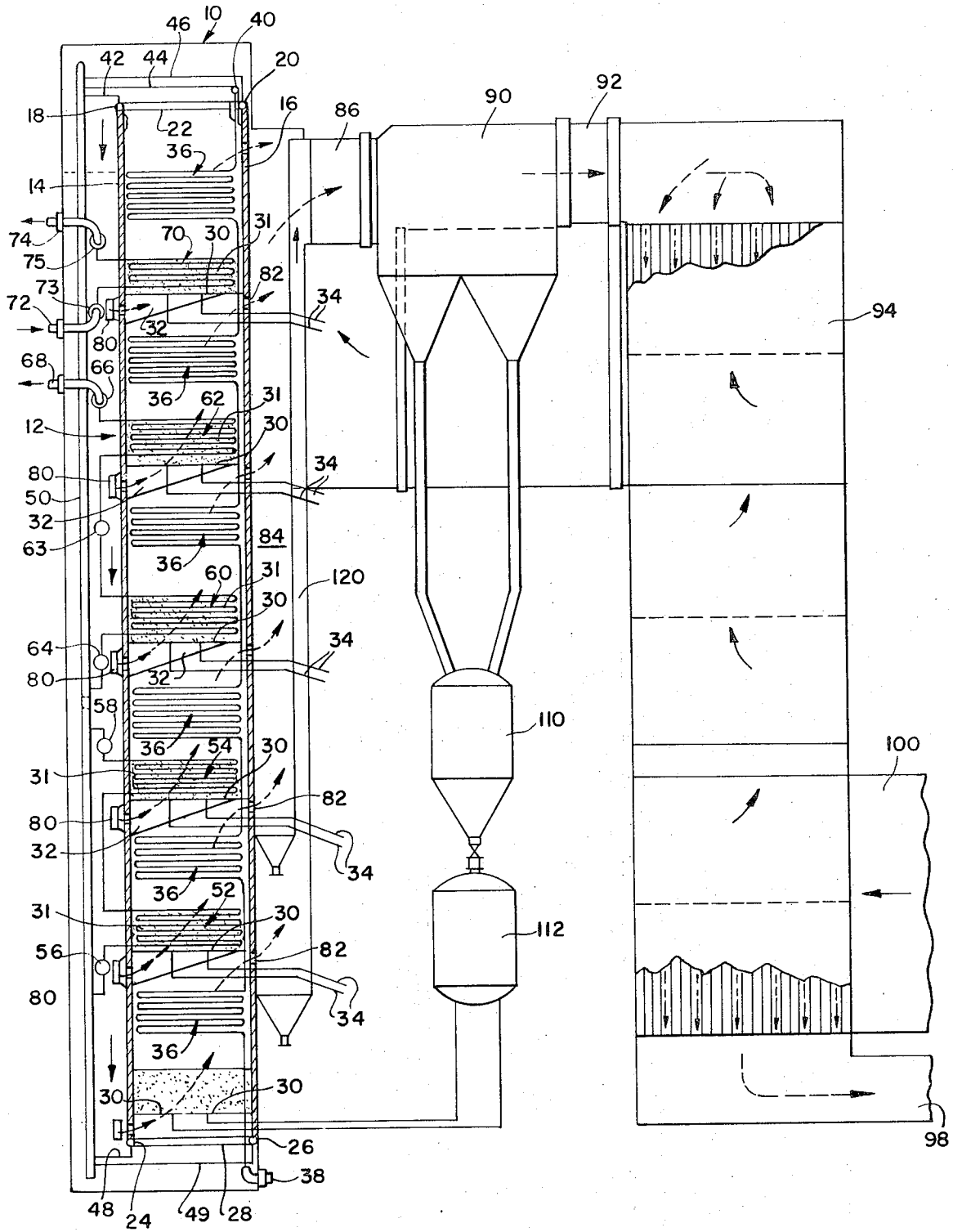


FIG. 1.

SHEET 2 OF 2

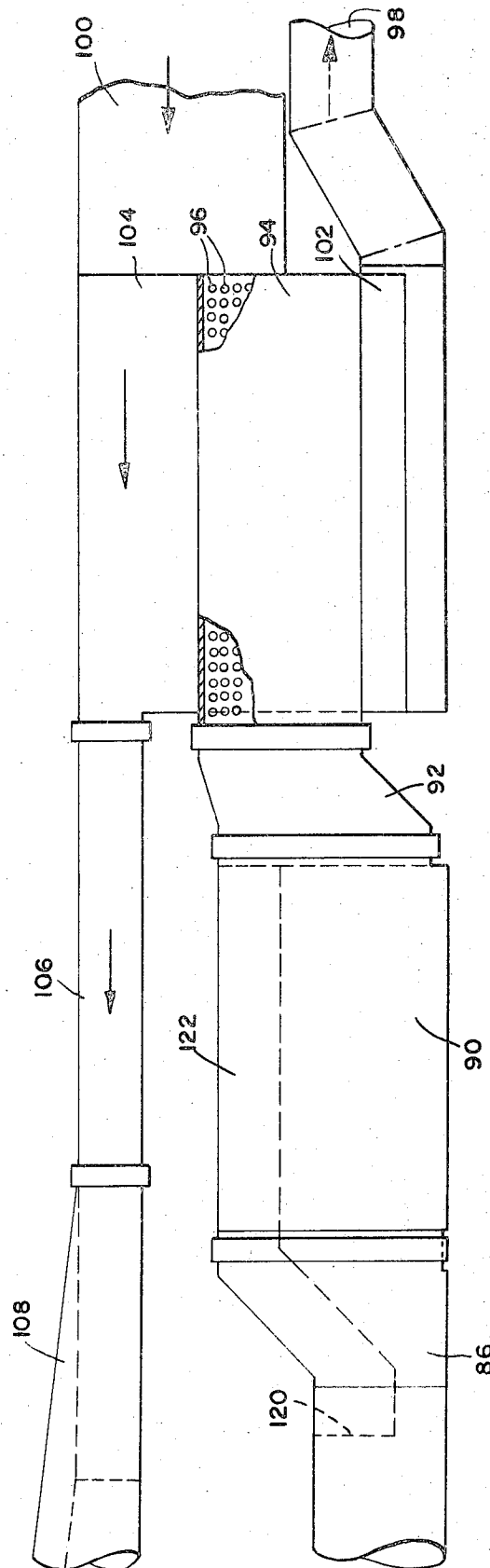


FIG. 2.

FLUIDIZED BED HEAT EXCHANGER

BACKGROUND OF THE INVENTION

This invention relates to a fluidized bed heat exchanger, and more particularly, to a steam generator which consists of a plurality of stacked fluidized beds for generating heat.

The use of a low-grade solid fuel, such as coal, is a well-known source of heat in the use of generation of steam. In some of these arrangements the fuel is disposed in a fixed bed with a chain grate stoker or the like utilized to promote its combustion, and water is passed in a heat exchange relation thereto to produce the steam. However, these arrangements suffer from several disadvantages including problems in handling the solid fuel while adding it to or removing it from the beds during operation. Also, a relatively low heat transfer is achieved and the bed temperatures are often non-uniform and hard to control.

Attempts have been made to utilize a fluidized bed to produce heat for generating steam due to the fact that a fluidized bed enjoys the advantages of an improved heat transfer rate, a reduction in corrosion, a reduction in boiler fouling, an increase in combustion efficiency, combustion at lower temperatures and a reduction in boiler size. In these arrangements, air is passed upwardly through a mass of particulate fuel material causing the material to expand and take on a suspended or fluidized state. However, there is an inherent limitation on the range of heat input to the water passing in a heat exchange relation to the fluidized bed, largely due to the fact that the quantity of air supplied to the bed must be sufficient to maintain same in a fluidized condition yet must not cause excessive quantities of the fuel material to be blown away.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a heat exchanger which enjoys the advantages of the fluidized bed yet enables a relatively large range of heat transfer to be obtained.

It is a further object of the present invention to provide a heat exchanger of modular construction which includes a plurality of stacked fluidized beds yet which can be manufactured with a minimum of components in a relatively simple manner.

Toward the fulfillment of these and other objectives, the heat exchanger of the present invention comprises a housing, a means of providing a plurality of vertically spaced beds of particulate fuel material disposed in said housing, a means of passing air through each of said fuel beds to promote the combustion of said fuel and maintain said compartments at predetermined temperatures, and a means for successively passing a heat exchange medium in a heat exchange relation to said fluidized beds.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic elevational view of the steam generator of the present invention; and

FIG. 2 is a top plan view showing a portion of the steam generator of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring specifically to FIG. 1 of the drawings, the

reference numeral 10 refers in general to a housing having several openings for the passage of air there-through and for receiving tubes as will be described in detail later. An enclosure 12 is defined within the housing and comprises a front wall 14 and a rear wall 16 shown in cross section, with each wall being formed by a plurality of finned tubes welded together in a conventional manner and extending for the entire length of the wall. A pair of side walls, identical to the front wall 14 and rear wall 16, are also provided but are not shown in FIG. 1 for the convenience of presentation.

A pair of headers, shown in end view by the reference numerals 18 and 20, are provided at the top of the enclosure 12, along with a header 22, it being understood that another header is disposed behind the header 22 as viewed in FIG. 1. In a similar manner, headers 24, 26, and 28 are disposed at the bottom of the enclosure 12 with it being understood that an additional header is disposed behind the header 28.

A plurality of horizontal, perforated air distribution plates 30 are disposed in a spaced relation in the enclosure 12 to divide the enclosure into a plurality of vertically stacked compartments, which define beds, designated by five reference numerals 31.

An air plenum chamber 32 extends below each of the plates 30 for distribution of air to the beds 31. Particulate fuel is fed as a dense phase mixture of air and fuel by means of a multiplicity of feed lines 34 which are associated with each of the beds 31. The feed lines 34 extend through a suitable opening provided in the rear wall 16, and pass through the plenum chamber 32 and air distributor plate 30 into bed 31 where the coal is discharged. The inlets 34 are adapted to receive the fuel in a conventional manner from a source such as a pneumatic feeder, which has not been shown in the drawings for the sake of simplicity.

A series of tubes, shown in general by the reference numeral 36, are disposed in the enclosure 12 and extend from an inlet 38 upwardly for the entire length of the enclosure 12 in a serpentine relationship to form a plurality of banks respectively disposed in the zone above the fluid bed 31 in an area where heat is primarily transferred by convection. Although only a single tube 36 is shown diagrammatically in FIG. 1, it is understood that a plurality of juxtapositioned tubes are provided, forming a tube bundle, that extends across the entire width of the enclosure 12.

A header 40 is disposed at the top of the enclosure 12 and registers with the tube bundle 36. As a result, a heat exchanger medium, such as water, passing in through the inlet 38 from a boiler feed pump, or the like, passes through the various banks of the tube bundle 36 whereby it is gradually heated before entering the header 40 for further distribution, as will be described in detail later.

A plurality of feeder tubes 42, 44, and 46 are connected to the headers 18, 40, and 20, respectively, at the upper portion of the enclosure 12 while a plurality of feeder tubes 48 and 49 are connected to the headers 24 and 26, respectively at the lower portion of the enclosure. Although not shown in the drawings, it is understood that additional feeder tubes are provided which are connected to the headers 22 and 28 and the other two headers not shown in the drawings, as discussed above.

Each feeder tube discussed above is connected to a respective downcomer conduit, one of which is shown

by the reference numeral 50, it being understood that several additional downcomer conduits extend immediately behind the downcomer conduit 50 as viewed in FIG. 1 and are similar thereto.

A pair of tube bundles 52 and 54 are disposed in adjacent compartments within the enclosure 12 and are connected in series between a pair of headers 56 and 58, respectively, which, in turn, are connected by the means of feeder tubes to separate downcomer conduits, similar to and extending behind the downcomer conduit 50.

In a similar manner, an additional pair of tube bundles 60 and 62 are disposed in adjacent compartments above the tube bundles 52 and 54 and are connected in series via a header 63. The tube bundle 60 is connected to a downcomer conduit extending to the rear of the downcomer conduit 50 via a header 64 and the tube bundle 62 is connected via a header 66 to an outlet conduit 68.

A tube bundle 70 is provided in the uppermost compartment in the enclosure 12 and is connected to an inlet conduit 72 via a header 73 and to an outlet conduit 74 via a header 75. It is noted that each tube bundle 52, 54, 60, 62, and 70 is submerged in its respective fluidized bed to effect a heat transfer of liquid passing therethrough as will be described in detail later.

A damper controlled air inlet 80 is provided adjacent each plenum chamber 32 for passing air in the directions indicated by the solid arrows in FIG. 1 through beds 31 of particulate material and fuel to fluidize the beds 31 in a conventional manner, it being understood that the velocity and rate of flow of the air passing through the beds is regulated so that it is high enough to fluidize the particulate fuel and to obtain economical burning or heat release rates per unit area of bed, yet is low enough to avoid the loss of too many fine fuel particles from the bed and to allow sufficient residence time of gases for good sulphur removal by a sorbent added to the fuel as also will be described in detail later.

The heated air, after passing through the fluidized beds, combines with the combustion products from the beds and the resulting mixture or, gas, exits through outlets 82 provided in the rear wall 16 as shown by the dashed arrows, where it flows into a chamber 84 disposed to the rear of the wall 16. The gas is directed from the chamber 84, through a duct 86 and to a cyclone type dust collector 90 which removes the fine coal particles entrained in the gas. Referring to FIGS. 1 and 2, the clean gas with the fines removed is then passed via a duct 92 to a tubular air heater shown in general by the reference numeral 94. This air heater comprises a series of tubes 96 for receiving the clean gas and directing same downwardly as shown by the dotted arrows in FIG. 1 where it exits through an outlet 98.

Air from an external source enters the system through an inlet 100 where it passes through a duct 102 adjacent the tubular air heater 94 and in a vertical direction as shown by the solid arrows whereby it is preheated. From the top of the duct 102 the preheated air is directed via ducts 104, 106, and 108 to the housing 10 whereby it is separated into the five separate streams of air entering the air plenums 32 through the inlets 80.

Referring again to FIG. 1, after being separated out of the gas stream by the dust collector 90, the fine par-

ticulate fuel material is directed to a dust hopper 110 and then into an injector 112 which injects the fines back into the lowest compartment in the enclosure 12 whereby it is fluidized and burned in a similar manner to the remaining fluidized beds. Air passing through this latter fluidized bed exits into an air chamber 120 adjacent the chamber 84 and is directed via a separate duct 122 (FIG. 2) to the tubular air heater 94.

In operation, each bed is started up by firing an auxiliary gas burner or the like (not shown) to the minimum fuel ignition temperature whereby fuel will be injected and combusted and each bed will continue burning after startup. The heat exchange medium, such as water, is introduced into the inlet 38 whereby it passes in series through each of the tube bundles 36 to raise its temperature to a predetermined level. It then passes from the uppermost tube bundle 36 to the header 40 and then from the feeder tubes 44 to the downcomer conduit 50 where it is directed into the header 56. From the header 56 the water passes in series through the tube bundles 52 and 54 whereby it is partially evaporated before exiting via a header 58 to a downcomer conduit located immediately to the rear of the downcomer conduit 50. The latter downcomer conduit directs the water-steam mixture downwardly to the feeder tubes 48 and to the header 24 whereby the mixture is passed upwardly through the finned tube wall 14 for the entire length thereof to further raise the temperature of the mixture. The mixture is then collected in the header 18, and fed, by means of the feeder tubes 42, to another additional downcomer conduit similar to downcomer conduit 50 and located therebehind, whereby it is directed to the sidewall header 28 via the feeder tubes associated therewith.

The water-steam mixture then passes completely up the latter sidewall to the header 22 where it is fed, via the associated feeder tubes to another downcomer conduit similar to the downcomer conduit 50 and extending therebehind, whereby it is directed to and through the other sidewall and the rear wall 16 in an identical manner. During the passage through the four walls of the enclosure 12, complete evaporation of the water into steam takes place.

After passing through the final wall 16, the steam is collected in the header 20 and passed, via the feeder tubes 46 to still another downcomer conduit where it is then passed, via a header 64, to and through the tube bundle 60, the header 63, and the tube bundle 62 thereby raising the temperature of the steam to superheat. The superheated steam is then collected in a header 66 and passed out through the outlet 68 where it can be used for other purposes such as for driving a steam turbine or the like.

The tube bundle 70 is provided to receive relatively low temperature steam which has previously been used in another stage of the plant such as a steam turbine, to raise its temperature for further use. In particular, the latter steam is received by an inlet 72 and passed, via a header 73, through the steam bundle 70 to raise the temperature of the steam before it exits via a header 73 and an outlet 74.

According to a preferred embodiment the particulate fuel is in the form of a mixture of crushed bituminous coal and limestone, with the latter functioning as a sorbent for the sulphur dioxide in combustion gases from the coal in accordance with conventional chemical theory. Since the low combustion temperatures and the

low excess air requirements also reduce the nitrogen oxide from the combustion gas, the latter contains a minimum of pollutants.

There are many other advantages of the arrangement of the present invention. For example, the use of the vertical stacked compartments defined by continuous walls considerably reduces the manufacturing costs and time, since it minimizes headers, interconnecting piping, and downcomers yet permits a maximum use of the heat transfer surfaces involved. Of course, the free movement of the particulate fuel in the fluidized bed promotes rapid heat transfer both within the bed and between the bed and the submerged tube banks. As a result, bed temperatures are uniform and easy to control.

The cost of construction is reduced by minimizing boiler cross sectional area and maximizing the number of components that are shop fabricated, such that the boiler dimensions can meet shipping, dimensional and weight limitations. Also, the start-up procedures are greatly simplified by assigning only one heating function to each bed, such that no bed must be started with uncooled tubes. Thus, the evaporating beds are started first with circulating water, and superheating beds are started last after steam has been generating. The start-up time is also reduced, and the heat required in the form of preheating ignitors is reduced as the flue gas from the evaporating beds preheats the air to the superheater. The assigning of separate heating functions to the individual beds also simplifies and improves steam temperature control by differential firing of coal to each bed. The modular construction simplifies load control, and a four to one turn down can be achieved by simply shutting down three modules. This also improves on load time as individual modules can be serviced without loosening the entire boiler system. Also, the economizer in the zone above the bed reduces gas temperature to nearly the same level as the air inlet temperature and water wall enclosure temperature, thereby minimizing differences in expansion of pressure parts or heat exchange components.

It should also be noted that a vertically stacked bed with a fin-tube water wall construction simplifies the circuitry and minimizes the number of headers, downcomers and feeder pipes. Thus, the fin-tube water wall construction has the following attendant advantages:

- a. Provides a support for heat transfer surface, pressure parts and fluid beds.
- b. Protects enclosure wall or shell from high temperature gases.
- c. Provides heat transfer surface thereby maximizing the utility of all components to serve their primary function of heat exchange.
- d. Provides a partition between the flue gas and inlet air.
- e. Reduces the surface requirements in the bed.
- f. Reduces cost by employing shop fabrication techniques.
- g. Reduces maintenance cost.

Still other advantages of the heat exchanger of the present invention include reduction in the corrosion of the tubes, etc., due to the relatively low combustion

temperatures available and a reduction in costs since cheaper construction materials can be used by virtue of the high heat transfer rates at the relatively low temperatures.

It is understood that the compactness and operation of the heat exchanger lends itself to incorporation in a modular system, since four or five units described above can be utilized in a side by side relation.

A latitude of modification, change and substitution is intended in the foregoing disclosure and in some instances some features of the invention will be employed with a corresponding use of other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the spirit and scope of the invention herein.

What is claimed is:

1. A heat exchanger comprising a housing, a plurality of vertically spaced beds of particulate fuel material disposed in said housing and defining a plurality of heat zones, means for passing air through each of said fuel beds to promote the combustion of said fuel and maintain said heat zones at predetermined temperatures, and means for successively passing a heat exchange medium upwardly through said heat zones in a heat exchange relation to said fuel beds to gradually raise the temperature of said medium.

2. The heat exchanger of claim 1 wherein each wall of said housing is formed by a plurality of continuous finned tubes for circulating said heat exchange medium.

3. The heat exchanger of claim 1 further comprising means to selectively direct said medium through at least one of said fuel beds after it has passed upwardly through all of said heat zones.

4. The heat exchanger of claim 3 wherein said medium is water, said water being partially evaporated during passage through said heat zones and being completely evaporated into steam during passage through said fuel bed.

5. The heat exchanger of claim 4 further comprising means to selectively direct said steam through at least one of said fuel beds to superheat the steam.

6. The heat exchanger of claim 1 further comprising means to direct said medium outwardly from and back into said housing after it has passed through said heat zones.

7. The heat exchanger of claim 1 wherein said air combines with the combustion products from said fuel beds as it passes through said fuel beds to form a heated gas, and further comprising means to direct said heated gas in a heat exchange relation to said air before it passes through said fuel beds.

8. The heat exchanger of claim 7 wherein a portion of said fuel material is entrained in said gas, and further comprising means to separate said portion of fuel material from said gas and direct said portion of fuel material to one of said fuel beds.

9. The heat exchanger of claim 1 wherein said heat zones are located immediately above their respective beds.

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