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DILUTE PHASE PARTICULATE MATTER REACTOR-HEAT EXCHANGER

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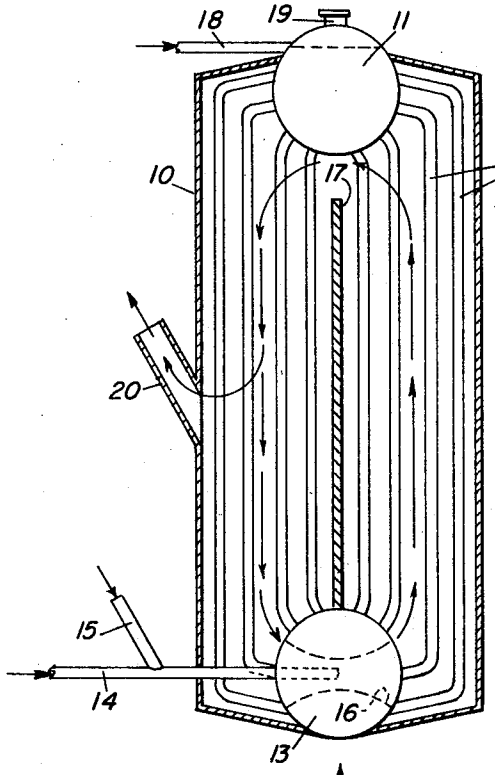


FIG. 1

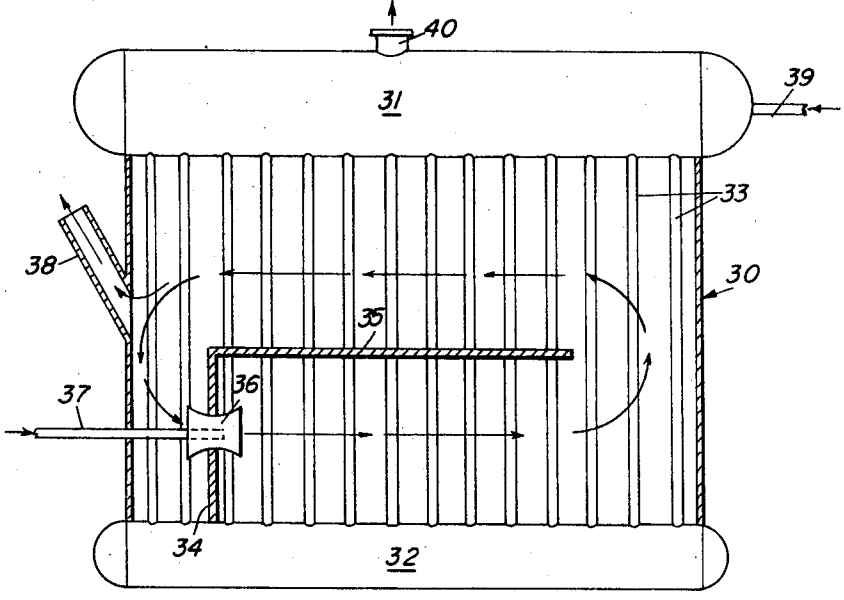


FIG. 2

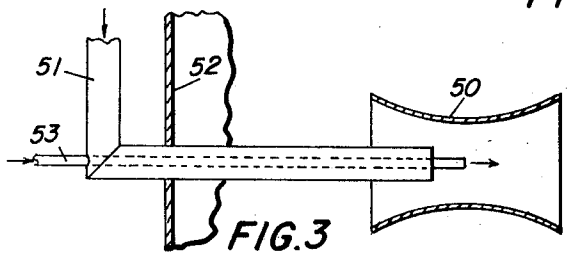


FIG. 3

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DILUTE PHASE PARTICULATE MATTER REACTOR-HEAT EXCHANGER

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ABSTRACT OF THE DISCLOSURE

Heat is extracted from circulating gases and particulate matter by dilute phase contact with heat exchange surfaces. In a specific embodiment, particulate coal is burned as a recirculating dilute phase gas suspension in a boiler-heat exchange chamber.

INTRODUCTION

The burning of solid fuel in a dilute phase gas suspension is an established art. Usually the fuel, for example coal, is introduced into the burner area or furnace in a finely divided state. In order to insure complete combustion of solid fuel particles, significantly greater fuel retention time in the burning area must be provided as compared to oil and gas. This in turn places definite upper limits on the heat reelase per unit volume of the furnace chamber. These limits are much lower than those of oil and gas fired units thus dictating much larger furnace dimensions for the same capacity.

It is also well established that combustion within a fluidized bed can provide an extremely high heat release per unit volume and particulate fuels such as coal can be burned in such beds. By providing heat exchange means such as a coil immersed within the bed, heat exchange rates many times that of conventional systems may be achieved between the fluidizing gas, the particulate bed and the heat exchange means. Thus, the fluidized bed system offers an attractive combination of high heat release, high heat transfer and extremely small size.

However, the fluidized bed combustion system also suffers some significant disadvantages. Combustible content of the ash residue is often extremely high. Fly ash entrained in the exiting flue gas may contain as much as 70% carbon and may represent a loss of as much as 15% of the heating value of the fuel. Auxiliary systems must be employed to recover the combustibles contained in the fly ash. Another disadvantage of the fluidized bed combustion system lies in its lack of control flexibility. A fluidized bed characteristically has a small turn-down ratio; that is the ratio of maximum fluidizing gas flow to minimum fluidizing gas flow may only be varied over a small range without disruption of the fluidized bed.

It has now been found that many of the advantages of both the fluidized bed combustion and a conventional furnace may be obtained in a single unit. A combustion or reaction zone is provided having a semiclosed loop configuration in which oxidizing or reacting particulate matter is continuously recirculated. In a preferred embodiment, heat exchange surfaces are placed within the combustion or reaction zone.

DETAILED DESCRIPTION OF THE INVENTION

The invention will be more clearly understood from the following description of a preferred embodiment wherein reference is made to the accompanying drawings:

FIG. 1 is a transverse sectional view of the reactor-heat exchanger illustrating a vertical baffling arrangement.

FIG. 2 is a longitudinal sectional view of the reactor-heat exchanger illustrating a horizontal baffling arrangement.

FIG. 3 illustrates an alternative nozzle arrangement for use in the device.

Referring now to FIG. 1, the device comprises a housing **10** enclosing a reaction volume. In this embodiment, the device is designed for the evaporation of liquids such as water. Disposed within the upper part of housing **10** is a steam drum **11** which is connected by means of heat exchange conduits **12** to a lower drum **13**.

A relatively high velocity stream of oxidizing gas, preferably air, is injected into the system via conduit **14**. Particulate fuel, preferably in a relatively finely-divided state, is introduced into the system by way of line **15**, where, after mingling with the oxidizing gas, the fuel is injected into the reactor. Conduit **14** terminates in the central portion of a converging-diverging throat **16** and forms in conjunction with that throat an eductor-type nozzle. Kinetic energy derived from the injected air causes circulation of combustion gases and fuel particles in a semiclosed loop as shown by the arrows. Velocity of the injected air must be sufficiently great to maintain the velocity of the circulating gases above the terminal or settling velocity of the particulate material carried by the gases. Baffle member **17** extends upwardly from drum **13** so as to define a circulation path encompassing a major portion of the volume enclosed by housing **10**. Member **17** may be constructed of refractory material or of a high temperature alloy and may be of water cooled construction.

A portion of the circulating combustion gases is continuously removed from the reactor through breeching **20**. Concentration and size of particulate matter, generally ash, carried by the exiting combustion gases is controlled by adjusting the angle formed by the juncture of breeching **20** with housing **10**. Control may also be accomplished by adjusting the velocity of the gases exiting through breeching **20** by varying the exit area.

In operation, a liquid such as water is introduced into the upper drum **11** through feed line **18**. Steam generated in the heat exchange tubes **12** is liberated in the upper drum and is discharged by way of line **19**. Fuel, such as pulverized coal, is injected into the reactor and circulates in a loop configuration until combustion is essentially complete. Burning coal particles and circulating fly ash impinge upon the heat exchange tubes resulting in an extremely high heat transfer rate. It is well recognized that combustible content of fly ash varies inversely with its particle size. By allowing only extremely small particles to be carried from the reactor in the existing flue gas, substantially complete combustion is assured.

Referring now to FIG. 2, there is shown another embodiment of the invention. In this embodiment housing **30** encloses a reaction or combustion volume of any convenient size and shape. As in FIG. 1, this embodiment illustrates a device designed for the evaporation of liquids such as water. A steam drum **31** is disposed within the upper portion of housing **30** and is in communication with a lower drum **32** by means of heat exchange tubes or conduits **33**.

Circulation of combustion gases and fuel particles is directed in a semiclosed loop, as is shown by the arrows, by means of baffle members **34** and **35**. Baffle member **34** is preferably disposed in a vertical position near one end of the device and extends from the lower drum to a point from about ⅓ to about ⅔ of the distance between the upper and lower drums. Baffle member **35** is preferably disposed in a generally horizontal attitude connecting with the upper edge of baffle **34** and providing a barrier to vertical circulation over a major portion of the area enclosed by housing **30**.

Mounted on and extending through vertical baffle member **34** is a converging-diverging throat **36** forming in conjunction with conduit member **37** an eductor-type nozzle. A relatively high velocity stream of oxidizing gas, preferably air, entering through conduit **37** causes a forced circulation of gases and fuel particles in a semiclosed loop configuration. Solid particulate fuel may be introduced into the device as a pneumatic suspension carried by the air stream entering through conduit **37**. While only one eductor nozzle is illustrated, any number of additional nozzles may be used in larger devices.

As in the device of FIG. 1, a portion of the circulating combustion gases is continuously removed from the reactor via breeching **38**. Concentration and size of particulate matter carried by the exiting combustion gases may be controlled by adjusting the angle formed by breeching **38** with housing **30**. Effectively then, the breeching acts as a pneumatic classifier passing only the smaller sizes of particulate matter from the reactor.

In operation, a liquid to be heated is introduced into the upper drum **31** by means of line **39**. Vapor generated in heat exchange tubes **33** is liberated in the upper drum and discharged from the system via line **40**.

Another embodiment of the eductor nozzle and gas entry conduit is illustrated in FIG. 3. A converging-diverging throat **50** may be mounted within the reactor in the manner shown in either FIG. 1 or 2. A gas entry conduit **51** passes through reactor housing wall **52** and terminates coaxially within throat **50** to form in cooperation therewith an eductor-type nozzle. Mounted coaxially within gas entry conduit **51** is fuel conduit **53** which preferably terminates within throat **50** but beyond the end of the gas entry conduit. Particulate fuel, such as pulverized coal, may be introduced as a pneumatic suspension using air, for example, as a carrier gas.

This arrangement provides thermal shielding for the injected fuel stream until it mixes with combustion air and thereby obviates problems of premature combustion within the fuel entry conduit. The axial area between conduits **51** and **53** functions also as a preheater for combustion air.

In any arrangement, ignition at start-up may be established by introducing preheated air or combustion gases generated by an external source through the gas entry conduit; line **14** of FIG. 1 for example. Inert particulate matter such as fly ash may also be introduced during start-up. After the device reaches fuel ignition temperature, introduction of fuel along with combustion air is initiated. If desired or appropriate, an intermediate fuel (one with a lower ignition temperature than the primary fuel) may be used to bring up the temperature within the device to the ignition temperature of the primary fuel. When this temperature level is reached, primary fuel is substituted.

Although the device has been described as being specifically useful for the purposes of heat and steam generation, it is also useful in other applications using different fuels or no fuel at all. For example, the device may be used as a heat recovery system from either hot gases or hot particulate matter. Usable heat may also be extracted from exothermic chemical reactions other than combustion. This invention may also be used for the incineration of finely divided waste materials such as sawdust, plastic scrap, sewage sludge and the like. By restricting the amount of combustion air to less than the stoichiometric amount needed for complete combustion, sewage sludge or other carbonaceous material may be used for the production of manufactured gas.

What is claimed is:

1. A heat-extracting reactor device which comprises:

(a) a reaction chamber;

(b) baffle means within the chamber positioned so that they define a flow path for the circulation of gases and suspended solids in the form of a semi-closed loop encompassing a major portion of the volume enclosed by the chamber;

(c) heat extraction means in contact with the circulating gases and suspended solids;

(d) means to introduce a gas stream at a relatively high velocity into the reaction chamber;

(e) means to introduce particulate material into a zone of relatively high gas velocity within the reaction chamber;

(f) means to cause circulation of gases and particulate matter contained within the reaction chamber in a semi-closed loop configuration defined by the baffle means, and

(g) means to remove a gas stream from the reaction chamber, said means adapted to control the size and amount of particulate matter carried from the chamber in the exiting gas stream.

2. The device of claim **1** wherein the heat extraction means comprise an upper vapor-liquid containing drum and a lower liquid containing drum, the drums being in fluid communication by means of a plurality of heat exchange conduits, said conduits disposed within the reaction chamber and in direct contact with circulating gases and particulate matter.

3. The device of claim **2** wherein the gas stream introduction means comprises a tubular conduit passing through an exterior wall of said reaction chamber and terminating within the chamber.

4. The device of claim **3** wherein the means to cause circulation of gases and particulate matter comprise at least one converging-diverging throat which forms in combination with said tubular conduit gas introduction means an eductor-type nozzle.

5. The device of claim **4** wherein the means to introduce particulate material comprises a tubular conduit coaxially disposed within the tubular conduit gas introduction means.

6. The device of claim **4** wherein the means to remove a gas stream from the reaction chamber comprises a duct member and wherein the angle made by the duct member with the reaction chamber may be varied so as to control the size and amount of particulate matter carried from the chamber in the exiting gas stream.

7. The device of claim **6** wherein said eductor-type nozzle is disposed within the lower drum and wherein the baffle means extend vertically a major part of the distance between the lower and upper drums.

8. The device of claim **6** wherein the baffle means extend substantially vertically from the lower drum at a position near one end of the reaction chamber, the vertical extension of the baffle means terminating at a point from about one-third to about two-thirds the distance between the upper and lower drums, and thereafter the baffle means extending substantially horizontally for a major portion of the distance between the vertical portion of the baffle means to the far end of the reaction chamber and wherein at least one eductor-type nozzle is disposed within the vertical portion of the baffle means.

9. A method for the contacting of particulate material and gases in a heat-extracting reaction chamber which comprises:

(a) introducing a relatively high velocity gas stream into the chamber;

(b) causing circulation of particulate material and gases within the chamber by energy exchange with the incoming relatively high velocity gas stream, said circulation being in a semiclosed loop configuration encompassing a major portion of the volume enclosed by the chamber and in physical contact with a plurality of heat exchange surfaces disposed within the chamber;

(c) maintaining the velocity of the circulating gases greater than the terminal velocity of the particles in said gases;

(d) removing a gas stream from the reaction chamber, and

(e) controlling the size of particulate material carried from the chamber in the exiting gas stream.

10. The method of claim **9** wherein a stream of particulate material is pneumatically introduced into the reaction chamber and wherein a chemical reaction between the particulate material and the gases occurs within the chamber.

11. The method of claim **10** wherein the chemical reaction is combustion and wherein a particulate ash-containing fuel and air are introduced into the reaction chamber.

12. The method of claim **11** wherein a major portion of circulating particulate material comprises partially combusted fuel particles and particles of ash residue.

13. The method of claim **12** wherein the size of particulate material carried from the chamber in the exiting gas stream is controlled so that only particles comprising ash are removed from the chamber.

14. The method of claim **11** wherein combustion is initiated by externally preheating the incoming air stream to the self-ignition temperature of the fuel.

15. The method of claim **14** wherein the incoming air stream is preheated to the ignition temperature of an intermediate fuel having an ignition temperature substantially below that of the primary ash containing fuel after which intermediate fuel is introduced into the chamber until the chamber and circulating gases and particulate material are heated to a temperature sufficiently high to ignite the primary fuel.

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