

[54] **SOLID FUEL COMBUSTION SYSTEMS**

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[56] **References Cited**

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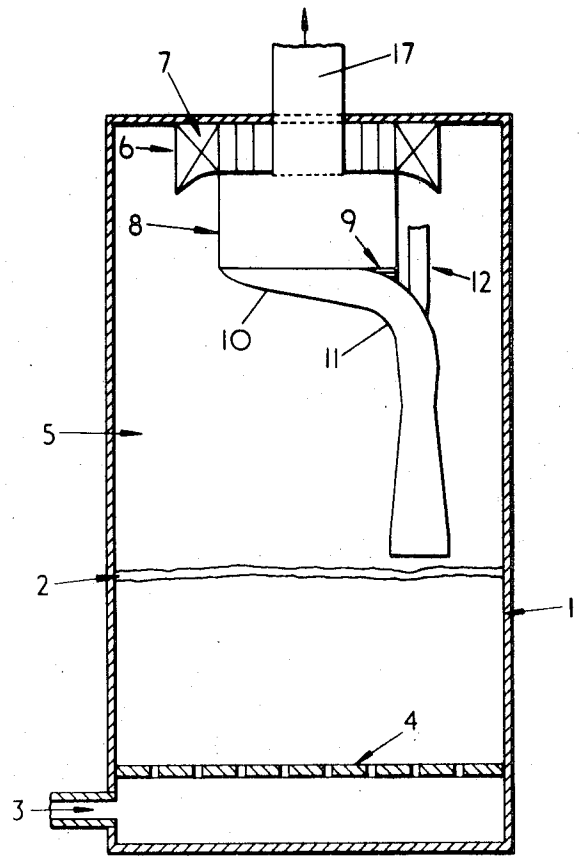
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[57] **ABSTRACT**

A particulate solid fuel combustion system includes a fluidized bed combustor adapted to contain a fluidized bed of inert particles in the lower region thereof. Particulate solid fuel is introduced into the bed to be burnt therein and exhaust gases derived from the combustion of the fuel are passed to a vortex combustion chamber included in the system. Fine particles of combustile material entrained in the gases are burnt within the vortex combustion chamber while relatively larger particles of combustile material are removed from the chamber to be reintroduced to the combustor at or adjacent the surface level of the fluidized bed contained therein. The invention also includes a method of operating the combustion system.

10 Claims, 2 Drawing Figures



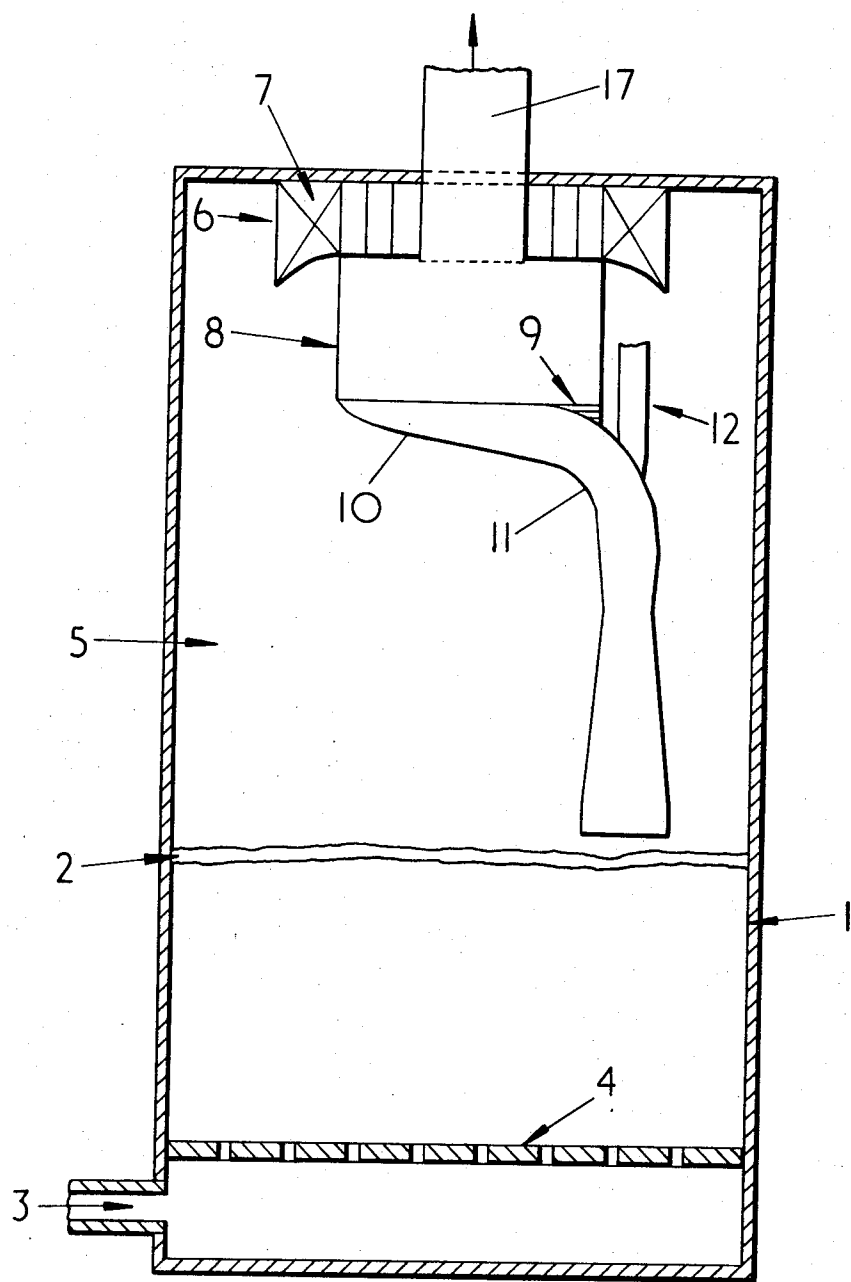
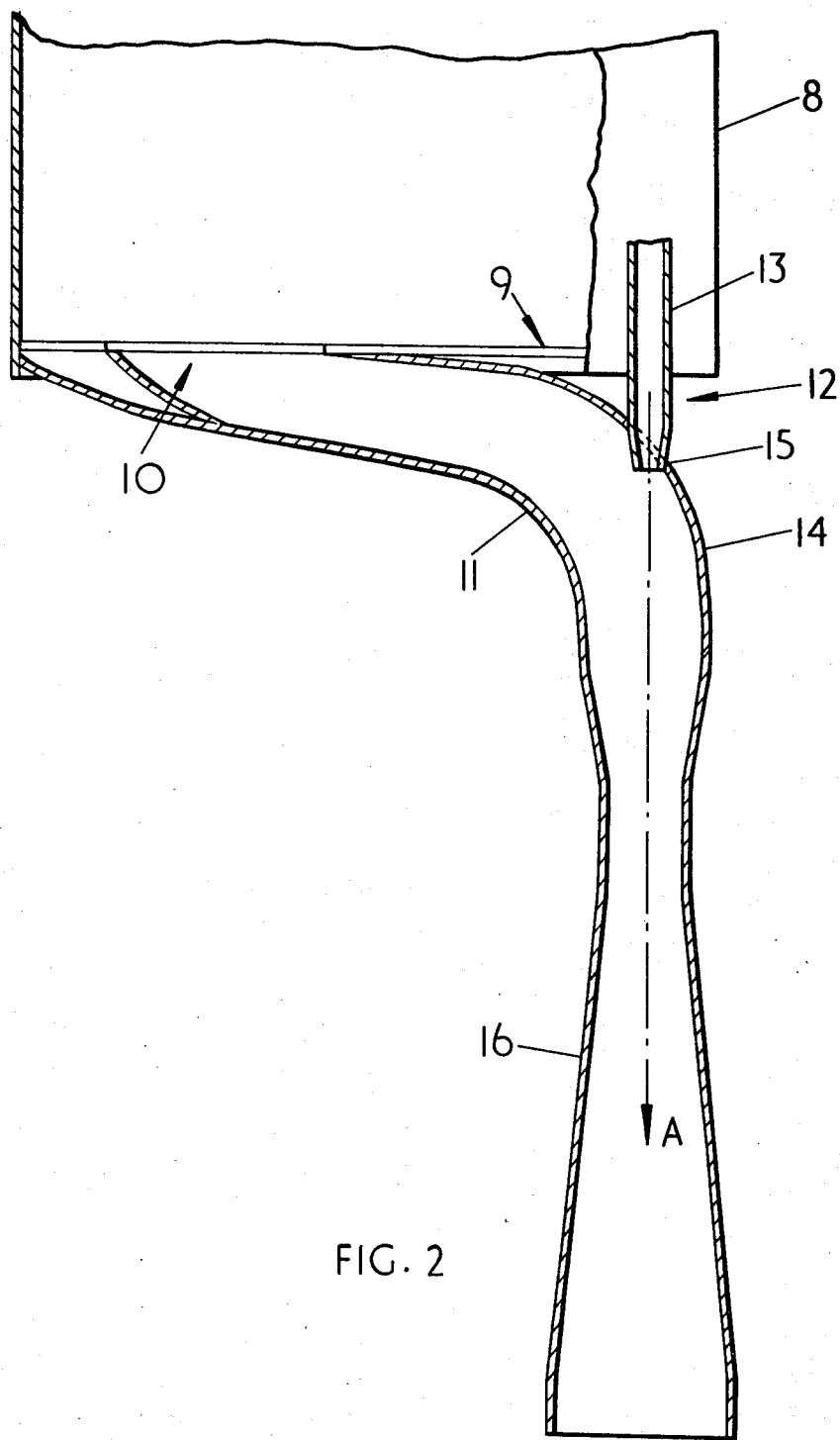


FIG. 1



SOLID FUEL COMBUSTION SYSTEMS

This invention relates to fluidized bed combustion systems and to a method of operation thereof.

The invention relates particularly to such systems for the combustion of particulate solid fuel. One of the major problems associated with fluidized bed combustion is that of the loss of combustible particulate material entrained in the exhausting gases of combustion. Particles of solid fuel are burnt in a fluidized bed of incombustible matter, e.g. ash, and both the solid fuel and the incombustible matter are maintained in the fluidized state by the upward flow of an oxygen-containing gaseous fluidized medium, for example, air. There is a tendency for fine particles of material to be entrained in the gases leaving the bed and passing into the free gas space above the bed, the particles thereafter being carried out with the gases to exhaust. This will occur if the free falling velocity of these fine particles is less than the velocity of the gases. Furthermore, when bubbles of gas form and ascend through the bed, bursting on the surface thereof, relatively larger particles of material are liable to be projected upwards a considerable distance into the gas space. The larger particles so projected may well reach the exhaust gas outlet and be "carried over" with the gas rather than fall back into the bed. Such larger particles generally comprise both incombustible and combustible material.

It is well known to employ cyclones for separating particulate material from its entraining gas and for collecting such material for recirculation to the fluidized bed thereby affording a further opportunity for the combustion of unburnt combustible material. However, there are a number of difficulties associated with the use of the cyclones. One of the major difficulties is that of the reintroduction of the material into the fluidized bed; this difficulty is mainly due to the fact that the pressure in the region of the cyclone where the material is collected is less than the pressure near the fluidized gas distributor where the material is to be introduced. Mechanical devices have been used for pumping particulate material into the bed against the gas pressure; however, the operation of such devices, especially at high temperatures is not satisfactory. An alternative to the pumping device is the "dip-leg" which comprises a tube extending from the material collecting region of the cyclone into the fluidized bed and terminating at a distance below the surface of the bed. It is a requirement that the particulate material passing through the dip-leg is in a sufficiently dense phase to behave as a liquid and thereby to prevent the passage of the gaseous medium up through the leg into the cyclone - the direction in which the pressure difference tends to cause flow; however, the phase density should not be so high that the material in the dip-leg behaves as a static bed of particulate material. If this latter condition exists the addition of further material from the cyclone into the dip-leg will not effect a corresponding discharge from the lower end of the dip-leg into the bed.

A further requirement is that the dip-leg be of sufficient height to ensure that the upper surface of the material in the dip-leg, behaving as the liquid, is below the position where the gas flow in the cyclone is liable to re-entrain the particulate material. Since the "

hydraulic head" of the material in the dip-leg must balance the total drop in gas pressure between that in the fluidized bed and that at the axis of the cyclone, and since the latter pressure difference will increase with operating pressure while the density of the material in the dip-leg is independent of pressure, the height of the material in the dip-leg will increase as the operating pressure is raised. The need for a sufficient height of dip-leg is likely to necessitate the overall size and cost of the fluidized bed combustion system being greater than would otherwise be required and this disadvantage will increase as the operating pressure is raised.

Another disadvantage of the dip-leg is that if the temperature of the material passing through the dip-leg is sufficiently high, combustion of the combustible content of that material may occur resulting in sintering thereof whereby agglomerates are formed which tend to obstruct the dip-leg.

It is thus an object of the present invention to obviate the above-mentioned difficulties and disadvantages associated with known systems.

According to the invention a particulate solid fuel combustion system includes a combustor adapted to contain a fluidized bed of particulate material having a free upper surface, a vortex combustion chamber having an upper inlet portion and a material discharge outlet, the inlet portion being in communication with an upper region of the combustor, a conduit extending from the outlet of the chamber to a relatively lower region of the combustor adjacent the said free upper surface, and ejector means incorporated in the conduit.

The upper inlet portion of the vortex combustion chamber is arranged to impart tangential velocity to gases within the chamber, the gases leaving the chamber through an axial discharge outlet. Within the chamber particles of material are subjected to a radially outward force due to the tangential component of the velocity and a radially inward drag force due to the radial component velocity. The dimensions of the vortex chamber are chosen so that relatively larger particles are collected around the periphery of the chamber and relatively smaller particles rotate about the axis of the chamber at radii which, depend, inter alia, upon their size. These smaller particles are subject to a velocity relative to that of the gas approximately equal to the radial component of the gas velocity. This relative velocity promotes the burning of the particles.

The material discharge outlet of the vortex chamber is conveniently located at or adjacent the base of the chamber at its periphery, and the conduit communicates with said outlet tangentially of the chamber. In use the larger particles are concentrated in a stream of gas which is a small proportion of the total gas flow in the chamber; said larger particles are directed to the periphery of the chamber and leave the chamber in said stream through the material discharge outlet and thence to the conduit.

The vortex chamber may conveniently be installed within the combustor in the upper region thereof. In this case directional vanes are arranged around the periphery of the inlet portion of the vortex chamber and are used to impart the necessary tangential component of velocity within the chamber. The vortex chamber has an axial discharge outlet which passes through the top of the combustor. The conduit extends

from the combustion chamber substantially vertically downwardly within the combustor.

Alternatively the vortex chamber may be located externally of the combustor in which case a duct conveys the gas and suspended particles from the combustor to the vortex chamber, the inlet portion of which may be any one of the several forms suitable for imparting the necessary tangential velocity; the conduit extends from the material discharge outlet of the combustion chamber and into the lower region of the combustor at a location adjacent, in use, the surface level of the fluidized bed.

In either alternative, it is preferred that the open end of the conduit terminates, in use, in the lower region of the combustor at a distance of between 0 and 12 inches above the surface level of the bed. As a further preference the open end of the conduit terminates, in use, at a distance of 6 inches above the surface level of the bed.

It will be appreciated that more than one vortex combustion chamber may be used in the system.

The ejector means preferably comprises a tube extending partially into the conduit axially thereof, said tube being provided for supplying pressurized fluid, for example, air into the conduit to induce flow of particulate material within the conduit and subsequently to entrain and transport the particles to the surface of the fluidized bed.

The invention also includes a method of operating a particulate solid fuel combustion system wherein particulate solid fuel is burnt in a fluidized bed of particulate incombustible material fluidized by a gaseous medium, exhaust gases of combustion are introduced into a vortex combustion chamber wherein fine particles of fuel entrained in the gases are burnt in the chamber, and relatively larger particles are removed from the chamber and are returned to a region adjacent to the surface of the bed.

By way of example only, one form of particulate solid fuel combustion system according to the invention is described below with reference to the accompanying drawings, in which:

FIG. 1 is a diagrammatic layout of a system; and

FIG. 2 is a part sectional side view of a detail of the system shown in FIG. 1.

Referring to FIG. 1 a particulate solid fuel combustion system includes a combustor 1 adapted to contain a fluidized bed of incombustible particulate material e.g. ash, in the lower region thereof. In the Figure the combustor 1 is shown containing a fluidized bed an upper level of which is indicated by the reference 2. The combustor 1 has a fluidized gas inlet 3 located towards the base thereof, and is provided with a gas distributor in the form of a support grid 4 located in the lower region of the combustor above the inlet 3. A fuel inlet (not shown) is situated at a level above the support grid 4 so as, in use, to introduce fuel into the fluidized bed.

In an upper region 6 of the combustor 1 is located a vortex combustion chamber 8 into which in use exhaust gases of combustion, issuing from the fluidized bed are directed by vanes 7 through an upper inlet portion of the combustion chamber. The vanes 7 are positioned within the upper inlet portion so as to create a vortex flow within the chamber 8. The chamber 8 includes a

base 9 which is provided with a material discharge outlet 10 situated near the periphery thereof and which communicates with a conduit 11, the conduit being arranged tangentially of the base 9. The conduit 11 includes an ejector unit 12 which will now be described in detail with particular reference to FIG. 2.

Referring to FIG. 2 the ejector unit 12 comprises a pipe 13 which enters the conduit 11 at a location near the discharge outlet 10 but down-stream thereof. The conduit 11 has an elbow section 14 having an aperture 15 formed in the outer radial portion thereof, the pipe 13 extending partially into the conduit as shown. The aperture 15 is located in the elbow section so that the longitudinal axis of pipe 13 is, in position, coincident with the axis of a further section 16 of the conduit 11. The section 16 extends vertically downwardly as in FIG. 1 and terminates at a short distance above the free surface, in this instance 2, of the fluidized bed.

The operation of the system is as follows:

Air, or other suitable gas medium, is introduced through inlet 3 so as to pass upwardly through the support grid 4 and thereby to fluidize particles of material forming the fluidized bed contained in the lower region of combustor 1. Particulate fuel is introduced through the fuel inlet (not shown) into the fluidized bed to be burnt in a fluidized state therein. Exhaust gases derived from the combustion of the fuel leave the bed and pass upwardly towards the upper region 6 of the combustor 1; at this point the gases and any particulate material entrained therein are directed into the vortex combustion chamber 8 through the upper inlet portion thereof by vanes 7 which induce a vortical flow. The particulate material includes fine particles of combustible material together with relatively larger particles of combustible material. The fine particles of material are burnt within chamber 8 and subsequently the resultant residue, i.e. ash, is carried out by the combustion gases and passes from the chamber 8 to an axial outlet 17 for discharge from the system. However, relatively larger particles are carried to the periphery of the base 9 of chamber 8 and pass through outlet 10 into conduit 11. Compressed air or other suitable gas medium, is supplied to the pipe 13 of ejector unit 12 so as to induce flow of the larger particles through conduit 11 and thereafter to entrain them within the conduit, the larger particles being transported in the direction of arrow A shown in FIG. 2. The entrained particles are directed through section 16 of conduit 11 and are discharged therefrom on to surface 2 of the fluidized bed.

As the material is entrained in pressurized air or other gas, the difficulty of pressure difference associated with the known systems is thus obviated.

I claim:

1. A particulate solid fuel combustion system including a combustor, a relatively upper region and a relatively lower region in the combustor, the relatively lower region being adapted, in use, to contain a fluidized bed of particulate material to a desired level therein, a vortex combustion chamber, an upper inlet portion and a material discharge outlet in the said chamber, the inlet portion of the chamber being in communication with the said relatively upper region of the combustor, a conduit extending from the material discharge outlet of the chamber to the said relatively lower region of the combustor adjacent, in use, the

desired bed level, and ejector means incorporated in the conduit.

2. A system according to claim 1 wherein the combustion chamber is located within the relatively upper region of the combustor.

3. A system according to claim 2 including directional vanes located in the upper inlet portion of the vortex combustion chamber, the vanes being spaced apart peripherally of the chamber whereby, in use, a vortical flow is induced in the chamber by the vanes.

4. A system according to claim 2 wherein the conduit extends substantially vertically downwardly within the combustor, and the conduit is connected to the material discharge outlet of the vortex combustion chamber substantially tangentially thereto.

5. A system according to claim 1 wherein the vortex combustion chamber is located externally of the combustor.

6. A system according to claim 5 including an outlet in the relatively upper region of the combustor, and a duct interconnecting the said outlet of the combustor and the said upper inlet portion of the vortex combustion chamber, the duct being connected to the upper inlet portion substantially tangentially thereto.

7. A system as claimed in claim 5 wherein the conduit is connected to the material discharge outlet of the vortex combustion chamber substantially tangentially thereto, the conduit extending into said relatively lower region of the combustor adjacent to the desired bed level.

8. A system as claimed in claim 1 wherein the ejector means extends into the conduit axially thereof,

downstream of the material discharge outlet of the vortex combustion chamber.

9. A system as claimed in claim 1 wherein the ejector means comprises a tubular member adapted to receive a higher pressure flow of a gaseous medium therethrough, whereby the flow induces and entrains material discharged through the material discharge outlet of the vortex combustion chamber.

10. A method of operating a particulate solid fuel combustion system said system including a combustor, a lower region of the combustor being adapted, in use, to contain a fluidized bed of particulate material to a desired level therein, a vortex combustion chamber, an upper inlet portion and a material discharge outlet in the said chamber, the inlet portion of the chamber being in communication with an upper region of the combustor, a conduit extending from the material discharge outlet of the chamber to a lower region of the combustor adjacent the desired bed level, and ejector means in the conduit including the steps of introducing an upward flow of a gaseous medium in the bed of particulate material, whereby the bed is fluidized and has a free upper surface, introducing particulate solid fuel into the bed, burning the fuel within the bed, introducing exhaust gases derived from the combustion of the fuel into the vortex combustion chamber, burning fine particles of fuel entrained in the gases within the combustion chamber, effecting removal in the chamber of relatively larger particles from the gases, and passing the larger particles from the vortex combustion chamber to the fluidized bed adjacent to the free upper surface level thereof.

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