A fluid-bed heat exchanger (36) constitutes a component of a fluid-bed combustion reactor system (10) for establishing heat transfer from heated particulate material fluidized within the fluid-bed heat exchanger (36) to heat transfer means (62) contained within said fluid-bed heat exchanger. The heat transfer means are internally carrying a heat-transfer medium. The fluid-bed heat exchanger comprises gas inlet means (86) for the introduction of a non-aggressive, substantially oxygen-free gas for the fluidization of said particulate material by means of the non-aggressive, substantially oxygen-free gas for preventing the formation of deposits on the heat transfer means and for preventing the corrosion of the heat transfer means.
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A fluid-bed heat exchanger, fluid-bed combustion reactor systems and methods for the operation of a fluid-bed heat exchanger and a fluid-bed combustion reactor system.

This invention concerns novel techniques of operating fluid-bed reactors, particularly fluid-bed heat exchangers for particulate material, for combustion of fuel comprising alkali, sulphur, chloride, carbon, nitrogen or the like.

Fluid-bed systems are used in a number of processes, wherein a good contact between solid particulate material and gas is desired. Examples are heat exchange, reactions with heterogeneous catalyst and reactions directly between solid matter and gases. The fluid-bed principle may briefly be explained in that the solid particulates are affected by a fluidization gas introduced from below, it being within certain constraints possible hereby to suspend the particles within a body of particulate materials and keep them suspended, even though the gas flow velocity does not need to rise to a level where single particles except for the very smallest ones would be entrained and carried away by the gas flow. Under such conditions the individual particles are freely movable, but the body of the particulate material will exhibit an upper surface, i.e. it behaves like a liquid from which the name fluid-bed. Hereby, obviously a very large area of contact between the solid particulates and the applied gas is achieved.

Examples of fluid-bed reactors or reactor systems are disclosed in DE publication 33 46 255, EP 0 332 360, EP 0 036 177 DK 160 166, DK 153 769, DE 37 41 935, EP 0 283 967, EP 0 304 111, EP 0 543 757, WO 82/00701, WO 89/05942, WO 92/17415 and US 5 014 652 to which patent applications and patents reference is made and which US patent 5 014 652 is hereby incorporated in the present specification by reference.

In connection with a fluid-bed reactor, particularly a fluid-bed heat exchanger for particulate material, such as e.g. the fluid-bed heat exchanger disclosed in the above EPO 0 332 360, heat transfer systems are provided which normally comprise a water preheater, also designated an economizer, an evaporator, in which the water is evaporated, and a superheater, in which steam is superheated. These heat transfer systems operate at different temperatures and therefore have to be designed taking into consideration the heat transfer requirements and the
applicable temperatures.

The superheater in a fluid-bed is normally arranged in a more or less oxidizing environment, as the superheater tubes are arranged within the fluid-bed heat exchanger or in the exhaust gas duct. The superheaters arranged in the exhaust gas duct are in contact with the flue gas containing alkali chloride and the solid particles containing alkali, chloride, sulphur and the like, and are operated at a maximum steam temperature of 430-500°C. They usually have a lifetime of 7-10 years when using an appropriate material for construction thereof.

The superheaters which are arranged in a fluid-bed heat exchanger for particulate material which is fluidized with air or other oxidizing gas may be exposed to both an oxidizing and a reducing environment. If deposits are formed on the superheater tubes, reducing conditions are prevailing in the border layer between tubes and deposit. The superheaters arranged in the heat exchanger for particulate material only come into contact with the solid particles containing chloride, sulphur and alkali and evaporated gases herefrom (small amounts in relation to the flue gas) and are operated at a maximum steam temperature of approx. 540°C. They usually have a lifetime of 4-7 years when using an appropriate material for construction thereof.

Alkali, sulphur and chloride in the fuel may give rise to amounts of alkali, sulphur and chloride in the bed material too, along with chemical compounds depending on the process conditions (temperature and gas and solid compositions). Some of these materials may under certain circumstances form deposits on "cold" surfaces and may be involved in an undesired corrosion process depending on process conditions. The problem generally relating to the corrosion of heating surfaces of heat exchanges are discussed in an article by R.U. Husemann: "Korrosionserscheinungen und deren Reduzierung an Verdampfern und Überhitzerbauteilen in kommunalen Müllverbrennungsanlagen", "VGB Kraftwerkstechnik 72(1992), Heft 10", p. 918-927.

It is common general knowledge that the chloride corrosion rate is depending on the metal surface temperature and has a maximum in the temperature area of 600-650°C.

The oxygen content may vary through the particle layer depending on the amount of uncombusted carbon in the bed material led to the particulate heat exchanger. In the bottom of the particulate heat exchanger oxidizing conditions are prevailing along the firm surfaces
and in the emulsion phase. However, there is an oxygen-free environment on the tube surface (underneath the deposit). In the top of the particulate heat exchanger reducing conditions may in many instances be prevailing both along the surfaces and in the emulsion phase. Underneath the deposit an oxygen-free environment may exist. The circumstance that a deposit may be formed on the heating surface, that chloride and sulphur are present in the deposit and that oxygen is present in the environment surrounding the outer surface of the deposit, give rise to chloride and sulphide corrosion of the heating surface.

In the present context, the terms "bottom", "top", "up" and "down" refer to the orientation relative to the vertical direction determined by the gravitational force. However, the terms may in some instances also refer to directions determined not only by the gravitational field, but determined by a virtual gravitational field generated by e.g. a high air stream flowing in a fluidizing bed from the bottom to the top which terms may due to other forces created by material flow or air flow etc. deviate from the vertical direction.

The obtaining of elevated steam parameters, i.e. elevated temperature and elevated pressure in the particulate heat exchanger (and longer lifetime of the particulate heat exchanger) is crucial for the obtaining of higher conversion efficiency, and therefore there is a strong incentive for increasing the steam temperature.

A necessity for obtaining elevated steam temperatures is that the process environment surrounding the superheater is altered so that substantially no corrosion occurs in the steam temperature range of 500-700°C.

An object of the invention is to provide novel techniques fulfilling the above necessity and in particular for reducing deposit on and/or corrosion of the heat transfer means, arranged in a fluid-bed reactor, particularly a fluid-bed heat exchanger for particulate material, for combustion of fuel comprising alkali, sulphur, chloride, carbon, nitrogen.

An advantage of the invention is that substantially no deposits are produced on the superheater, and corrosion by chloride or sulphide is also reduced markedly.

A feature of the present invention is that sintering of materials together in areas of the fluid-bed heat exchanger in which areas the fluidizing conditions are less than optimum are radically reduced as
compared to conventional fluid-bed coolers.

The above object, the above advantage, the above feature together with numerous other objects, advantages and features which will be evident from the below detailed description of the present invention are in accordance with a first aspect of the present invention obtained by a fluid-bed heat exchanger of a fluid-bed combustion reactor system and for establishing heat transfer from heated particulate material fluidized within said fluid-bed heat exchanger to heat transfer means contained within said fluid-bed heat exchanger and internally carrying a heat-transfer medium, said fluid-bed heat exchanger comprising gas inlet means for the introduction of a gas for the fluidization of said particulate material by means of a non-aggressive, substantially oxygen-free gas.

According to the present invention, it has been realized that the problems relating to corrosion of the heat transfer means of the fluid-bed heat exchanger, the deposition of material on the heat transfer means of the fluid-bed heat exchanger and the sintering of materials together within the fluid bed are radically reduced or basically to any substantial extent eliminated provided the fluidization of the particulate material is established by means of a substantially oxygen-free gas as oxidation or reduction processes are consequently eliminated within the fluid-bed heat exchanger.

In the present context, the term heat transfer is to be construed a generic term comprising any heat transfer means such as e.g. heat transfer tubes, evaporator tubes, superheater tubes, heat-pipe tubes etc.

In the present context, the term fuel is to be construed a generic term comprising any combustible material such as natural gas, gasoline, coal, straw material, wood material, municipal waste material or other cellulose material, biofuels etc.

The non-aggresive, substantially oxygen-free gas by means of which the particulate material is fluidized within the fluid-bed heat exchanger according to the first aspect of the present invention may be input to the fluid-bed heat exchanger directly through the gas inlet means in accordance with embodiments to be described below or alternatively according to a first embodiment of the fluid-bed heat exchanger according to the first aspect of the present invention be produced within the fluid-bed heat exchanger as the non-aggressive,
substantially oxygen-free gas is generated through the combustion internally within the fluid-bed heat exchanger of a combustable gas input to the fluid-bed heat exchanger along with atmospheric air through the gas inlet mean. The combustable gas may, thus, be constituted by e.g. natural gas which is input to the fluid-bed heat exchanger e.g. through a bottom-part thereof through nozzles and are used for the reduction of the content of oxygen of the atmospheric air which is input along with the natural gas through the above mentioned nozzles or, alternatively, through separate air inlet nozzles by the consumption of the content of oxygen of the atmospheric air or any other input gas containing oxygen through the combustion of the natural gas.

The non-aggressive, substantially oxygen-free gas by means of which the particulate material is fluidized within the fluid-bed heat exchanger according to the first aspect of the present invention may be generated by means of any appropriate means fulfilling the basic requirement that the gas in the present environment within the fluid-bed heat exchanger is non-aggressive and is substantially oxygen-free. According to a second embodiment of the fluid-bed heat exchanger according to the first aspect of the present invention, the fluid-bed heat exchanger comprises a combustion means for producing the non-aggressive, substantially oxygen-free gas from the atmospheric air through the elimination of oxygen from the atmospheric air through the combustion of fuel within the combustion means which may be constituted by e.g. a combustion engine or gas burner.

According to a third embodiment of the fluid-bed heat exchanger according to the first aspect of the present invention, the gas inlet means communicates with an exhaust duct of the fluid-bed combustion reactor for producing the non-aggressive, substantially oxygen-free gas from low oxygen content exhaust gas of the fluid-bed combustion reactor.

The requirement to the fluidizing gas of the fluid-bed heat exchanger as to providing the non-aggressive, substantially oxygen-free gas is fulfilled provided the gas is non-aggressive within the present environment and further provided the content of oxygen is less than 5% by volume, such as less than 2.5% by volume, preferably approx. 0% by volume.

According to a fourth embodiment of the fluid-bed heat exchanger according to the first aspect of the present invention, the non-aggressive, substantially oxygen-free gas is constituted by an inert gas
as the gas inlet means communicates with an inert gas supply for the supply of the inert gas, which may be constituted by e.g. argon, nitrogen, carbon dioxide or the like or any combination thereof.

According to a fifth embodiment of the fluid-bed heat exchanger according to the first aspect of the present invention, the non-aggressive, substantially oxygen-free gas may be constituted by steam as the gas inlet means communicates with a steam supply for the supply of steam to the fluid-bed heat exchanger.

Dependent on the application of the fluid-bed heat exchanger according to the first aspect of the present invention and also the gas to be used for fluidizing the particulate material within the fluid-bed heat exchanger, the fluid-bed heat exchanger may constituted a pressurized or alternatively a non-pressurized fluid-bed heat exchanger.

The heat transfer medium which is carried internally by the heat transfer means of the fluid-bed heat exchanger according to the first aspect of the present invention may be constituted by any appropriate heat transfer medium dependent on the specific application. In most applications, the heat transfer medium is constituted by water or steam or alternatively an inert gas such as carbondioxide, nitrogen or fluid or gaseous natrium or potassium, in particular provided the heat transfer means are constituted by so-called heat pipes.

In the above described first, second, third, fourth and fifth embodiments of the fluid-bed heat exchanger according to the first aspect of the present invention, the provision of the non-aggressive, substantially oxygen-free gas is described as specific alternatives, however, the techniques according to the above described five alternative embodiments may be combined as e.g. recirculated flue gas may be used in combination with an inert gas, steam etc. for input directly into the fluid-bed heat exchanger or input to e.g. a combustion engine, a gas burner or similar oxygen consuming device or means.

It is to be realized that the combustion established within the fluid-bed heat exchanger or externally relative to the fluid-bed heat exchanger for the consumption of oxygen, i.e. the elimination of oxygen within the fluidizing gas which is used for fluidizing the particulate material within the fluid-bed heat exchanger may constitute a catalytic or alternatively a non-catalytic combustion dependent on the specific requirements and the specific application etc. It is further to be realized that the overall operation of the fluid-bed heat exchanger may
be established by controlling the input of the gas into the fluid-bed heat exchanger for controlling the flow of the non-aggressive, substantially oxygen-free gas produced from the gas input to the fluid-bed heat exchanger or constituted by the non-aggressive, substantially oxygen-free gas itself or, alternatively, by controlling the flow of particulate material input to the fluid-bed heat exchanger as is well known within the art per se or, further alternatively, in a combined operational mode in which the operation of the fluid-bed heat exchanger is controlled by controlling the input of the gas into the fluid-bed heat controller and also the flow or particulate material input to the fluid-bed heat exchanger.

The fluid-bed heat exchanger according to the first aspect of the present invention may be implemented in accordance with any relevant technique such as the technique disclosed in EP patent No. 0 332 360 and US patent No. 5 014 652 to which European patent reference is made and which US patent is hereby incorporated in the present specification by reference. Consequently, the fluid-bed preferably constitutes an upwards open vessel with a generally closed bottom wall and side walls, which gas inlet means is provided at which bottom wall of which upwards open vessel, and which fluid-bed heat exchanger further comprises at least one opening in the bottom wall for the discharge of particulate material from which fluid-bed heat exchanger.

The above object, the above advantage together with numerous other objects, advantages and features which will be evident from the below detailed description of the present invention are in accordance with a second aspect of the present invention obtained by a fluid-bed combustion reactor comprising a vertical reactor chamber including a reactor chamber lower portion, a reactor chamber upper portion and an exhaust duct at which reactor chamber upper portion for the withdrawal of exhaust gas and particulate material from which reactor chamber, and a fluid-bed heat exchanger for establishing heat transfer from particulate material transferred therefrom from which reactor chamber upper portion through which exhaust duct and fluidized within which fluid-bed heat exchanger to heat transfer means, such as tubes, contained within which fluid-bed heat exchanger and internally carrying a heat-transfer medium, which fluid-bed heat exchanger comprising gas inlet means for the introduction of a non-aggressive, substantially oxygen-free gas for the fluidization of which particulate material, so
as to generate which heat transfer to which heat transfer means without causing, to any substantial extent, corrosion of which heat transfer means through oxidation or reduction processes.

The fluid-bed combustion reactor according to the second aspect of the present invention and the fluid-bed heat exchanger according to the first aspect of the present invention preferably comprise any of the features of the fluid-bed combustion reactor and the fluid-bed heat exchanger, respectively, disclosed in the above EP patent and the above US patent.

The above object, the above advantage together with numerous other objects, advantages and features which will be evident from the below detailed description of the present invention are in accordance with a third aspect of the present invention obtained by a method for the operation of a fluid-bed heat exchanger for establishing heat transfer from heated particulate material fluidized within which fluid-bed heat exchanger to heat transfer means, such as tubes, contained within which fluid-bed heat exchanger and internally carrying a heat-transfer medium, which method comprising introducing a non-aggressive, substantially oxygen-free gas into which fluid-bed heat exchanger by means of gas inlet means for the fluidization of which particulate material, so as to generate which heat transfer to which heat transfer means without causing, to any substantial extent, corrosion of which heat transfer means through oxidation or reduction processes.

The above object, the above advantage together with numerous other objects, advantages and features which will be evident from the below detailed description of the present invention are in accordance with a fourth aspect of the present invention obtained by a method for the operation of a fluid-bed combustion reactor, comprising a vertical reactor chamber including a reactor chamber lower portion, a reactor chamber upper portion and an exhaust duct at which reactor chamber upper portion for the withdrawal of exhaust gas and particulate material from which reactor, and a fluid-bed heat exchanger for establishing heat transfer from particulate material transferred thereto from which reactor chamber upper portion through which exhaust duct and fluidized within which fluid-bed heat exchanger to heat transfer means, such as tubes, contained within which fluid-bed heat exchanger and internally carrying a heat-transfer medium, which method comprising introducing a non-aggressive, substantially oxygen-free gas for the fluidization of
which particulate material, to generate which heat transfer to which heat transfer means without causing, to any substantial extent, corrosion of which heat transfer means through oxidation or reduction processes.

In accordance with the teachings of the present invention, it has further been realized that a heat changer provided as a section of a downcomer connecting the reactor chamber lower portion with the reactor chamber upper portion of a vertical reactor chamber of a fluid-bed combustion reactor system may be operated without causing to any substantial extent the formation of deposits on the heat exchanger and corrosion of the heat exchanger.

According to a further aspect of the present invention, a fluid-bed combustion reactor system is provided comprising a vertical reactor chamber including a reactor chamber lower portion, a reactor chamber upper portion and an exhaust duct at said reactor chamber upper portion for the withdrawal of exhaust gas and particulate material from said reactor chamber, and a heat exchanger for establishing heat transfer from particulate material transferred thereto from said reactor chamber upper portion through said exhaust duct to heat transfer means, contained within said heat exchanger and internally carrying a heat-transfer medium, said heat exchanger constituting a section of a downcomer connecting said exhaust duct of said reactor chamber upper portion with said reactor chamber lower portion for the recirculation of at least part of said particulate material withdrawn from said reactor chamber.

It is contemplated that the heat exchanger provided within the downcomer in accordance with the further aspect of the present invention eliminates the problem associated with conventional fluid-bed super heaters as the particulate material which is recirculated by the downcomer contains carbon which reduces any oxygen present within the exhaust gas drawn through the downcomer which oxygen might else give origin to the formation of deposits on the heat exchanger and also give origin to the corrosion of the heat exchanger.

According to a still further aspect of the present invention, a method of operating a fluid-bed combustion reactor system, comprising a vertical reactor chamber including a reactor chamber lower portion, a reactor chamber upper portion and an exhaust duct at said reactor chamber upper portion for the withdrawal of exhaust gas and particulate
material from said reactor, and a heat exchanger for establishing heat transfer from particulate material transferred thereto from said reactor chamber upper portion through said exhaust duct to heat transfer means contained within said heat exchanger and internally carrying a heat-transfer medium, said heat exchanger being a sectional heat exchanger constituting a section of a respective downcomer, said method comprising allowing said particulate material to flow down through said downcomer.

Further objects, features and advantages of the invention will appear from the following description of preferred embodiments with reference to the accompanying drawing, wherein

Fig. 1 is a vertical sectional view of a first embodiment of a fluid-bed combustion reactor system illustrating three alternative ways of introducing fluidization gas according to the invention,

Fig. 2 is a reaction diagram illustrating the process conditions in the combustion of fuels,

Fig. 3 is a schematic view of a second embodiment of a combustion reactor system illustrating the technique of fluidizing particulate material within a fluid-bed heat exchanger by means of steam,

Fig. 4 is a schematic and partly sectional view of a third embodiment of a fluid-bed combustion reactor system also constituting a pressurized fluid-bed combustion reactor system including a fluid-bed heat exchanger,

Fig. 5 is a schematic and sectional view of a further embodiment of a heat exchanger constituting a sectional fluid-bed heat exchanger similar to the fluid-bed heat exchanger disclosed in US patent No. 5,273,000 to which reference is made and which is hereby incorporated in the present specification by reference, and

Fig. 6 is a schematic and partly sectional view of a further embodiment of a fluid-bed combustion reactor system comprising a downflow heat exchanger according to the present invention.

Reference is made to fig. 1, showing a vertical section through a fluid-bed combustion reactor 10 according to a first and preferred embodiment of the invention. This reactor 10 comprises as shown in the figure a bottom chamber 12 defined by a wall 14 and with a top chamber 16 arranged thereabove. The bottom chamber 12 is at the lower end provided with a discharge opening 18 with a valve mechanism 20 to allow removal of particle matters and ash, if necessary.

At a predetermined distance above the bottom outlet opening 18 a
manifold or plenum chamber 22 with nozzles for the introduction of fluidization air or fluidization gas is arranged. At the area below the manifold 22, the particles will not be fluidized unless other fluidization means are provided here, but the particles may slide downwards to the discharge opening 18 when the valve mechanism 20 is open.

The reactor 10 is provided with inlet ducts 24 for the introduction of particles, which may comprise fuel, inert particles, soluble reactants for the binding of undesired matter etc. Further inlets 26 for secondary reactor air may be arranged in order to allow the maintaining of a slow fluid-bed at the bottom, while a faster fluid-bed is maintained above the secondary air inlets. The operation of the fluid-bed is preferably controlled in accordance with the so-called "stage combustion technique" according to which a plurality of combustion stages are produced at different elevational levels within the fluid-bed reactor through the controlling of the concentration of oxygen to be combusted within the separate stages or sections within the fluid-bed reactor. Above the inlet 26 for secondary reactor air a further upper inlet 28 for the introduction of particulate materiale such as fuel, inert particle, soluble reactants for the binding of undesired matter etc. may be arranged as it may be advantageous to have the possibility of selecting between various levels of introduction of such particles.

The fluidization nozzles are provided with air/gas from blowers, each blower being provided with means to control the air/gas flow and each designated with the reference number 30. At sufficient amount of fluidization air, solid particles will be suspended by the air/gas flow and entrained by elutriation to arrive at the top chamber, where the flow is deflected sideways by a deflector 32.

The top chamber 16 has a larger cross sectional area than the reactor lower portion 12 and the air/gas velocity will therefore decrease in the top chamber. The air/gas may flow arround the deflector 32 to enter the exhaust duct 34 for flue gas. Due to the decreasing air/gas velocity in the top chamber and due to the change of flow direction, a substantial proportion of the particulate material entrained with the gas falls down into the particulate heat exchanger 36 arranged below the top chamber in accordance with a separation or sedimentation technique.

Exhaust gas exits through the exhaust duct 34 to arrive at the
cyclone 38, where further separation of solid particles from the exhaust gas takes place. Gas exits the cyclone 38 through the duct 40 and blows past further cooling surfaces, e.g. evaporator tubes 42 or alternatively superheater tubes, re heater tubes, heat pipes etc., a preheater or economizer 44 and an air preheater (not shown in the drawings, however disclosed in EP 0 332 360 and US 5 014 652 to which EP patent reference is made and which US patent is hereby incorporated in the present invention by reference). Particles separated from the exhaust gas in the cyclone 38 exits the cyclone at the bottom 46 and may move downwards through the downcomer 48 from the cyclone to be reintroduced into the primary reactor 10.

Particles dropped down into the particle heat exchanger 36 may move downwards herein and flow through a downcomer 50 returning the particles for reintroduction into the primary reactor 10. As shown in the drawings in figure 1, the particle heat exchanger is provided with controlable blower 30 blowing fluidization air through conduits 52 upwards through the particle heat exchanger through fluidization nozzles 54 in order to fluidize the bulk of particle in the particle heat exchanger 36. The upper surface of the bulk particles in the particle heat exchanger is shown in the drawings at 56.

The particle heat exchanger 36 comprises bottom wall 58 and side walls 60. The particle heat exchanger is provided with coolant tubes in a serpentine pattern sectionalized into two sections, which sections being designated the evaporator tube coil (not shown in the drawings, however disclosed in EP 0 332 360 and US 5 014 652 to which EP patent reference is made and which US patent is hereby incorporated in the present invention by reference) and the superheater tube coil 62. These tube coils carry water and/or steam and flow within each of the tube coils may be controlled separately. In the particle heat exchanger 36, bottom 58 opening 64 is provided for particle discharge. The opening 64 takes the particles down through a downcomer 50 from the superheater section while an opening (not shown in the drawings, however disclosed in EP 0 332 360 and US 5 014 652 to which EP patent reference is made and which US patent is hereby incorporated in the present invention by reference) carries particles down to the downcomer from the evaporator section (not shown in the drawings, however disclosed in EP 0 332 360 and US 5 014 652 to which EP patent reference is made and which US patent is hereby incorporated in the present invention by reference).
The superheater section downcomer 50 is shown shaped as an L with a relatively tall vertical portion and a relatively short horizontal portion at the lower end. As it may be seen in figure 1, an air jet 66 connected to a blower 30 with a blower control facility by a conduit 52 is arranged at the downcomer lower end. During normal operation, the downcomer will be filled with particles up to a level above the coolant tube coils in the particle heat exchanger. Blowing of air/gas through the jet 66 will carry particles through the downcomer horizontal portion and into the reactor as the resistance to the air blowing is lower this way. The pressure in the pillar of particles within the downcomer is normally so high that these particles will not be fluidized, but rather slide down-wards slowly by gravity in proportion to the amount removed at the bottom.

Particulate material within the fluid-bed heat exchanger 36 is fluidized by blowing of gas or air through an air plenum chamber with nozzles 70.

Reference is made to fig. 2, disclosing a reaction diagram illustrating the process conditions in the combustion of fuels containing sulphur in the fluid-bed with internal desulphurization using lime stone.

In combustion of fuels containing alkali chloride such as straw, other fertilized biofuels, English coals, municipal waste, chicken litter etc., in combination with fuels containing sulphur such as coal, oil etc. in the fluid-bed with internal desulphurization using lime stone there will additionally be formed inter alia:

\[
\begin{align*}
\text{Ox}: & \quad \text{Na}_2\text{SO}_4 (s), \ \text{K}_2\text{SO}_4 (s), \ \text{Na}_2\text{Ca}_2(\text{SO}_4)_3 (s) \ \text{and} \ \text{K}_2\text{Ca}_2(\text{SO}_4)_3 (s) \\
& \quad \text{NaCl}(g) \ \text{and} \ \text{KCl}(g) \\
& \quad \text{and}
\end{align*}
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\[
\begin{align*}
\text{Red}: & \quad \text{Na}_2\text{Si}_2\text{O}_5 (s), \ \text{K}_2\text{SiO}_3 (s) \ \text{and} \ \text{KCl}(s), \\
& \quad \text{NaCl}(g), \ \text{KCl}(g) \ \text{and} \ (\text{KCl})_2(g)
\end{align*}
\]

depending on whether there is oxidizing or reducing conditions, concentration of the individual constituents, temperature, pressure etc. Thus, the bed material contains a mixture of several of these compositions, fuel ash and the basic material which may be sand, fly ash, aluminium oxide particles etc.
The softening/adhesive temperature of the ash in the bed material very much depends on which Na and K compounds it contains. Under oxidizing conditions this temperature is essentially below the combustion temperature, bed material temperature and flue gas temperature, with which there is basis for deposits of adhesive ash on the substantially colder superheater tubes.

Under reducing conditions the softening temperature is normally somewhat higher than the bed material temperature. Therefore deposits are normally not produced.

Fig. 1 shows fluidized particles emulsion phase areas 72 within the particle heat exchanger 36.

Further, with reference to fig. 1, three alternative ways of introducing a non-aggressive, substantially oxygen-free fluidizing gas 86 are illustrated.

The first alternative is fluidization with recirculated flue gas, which flue gas being recirculated from exhaust gas outlet 84 through recirculation conduit 80. The flue gas is cooled before the fluidization gas blower 30, if necessary (not shown in the drawings, however disclosed in EP 0 332 360 and US 5 014 652 to which EP patent reference is made and which US patent is hereby incorporated in the present invention by reference) and fluidization gas 86 is introduced into the gas plenum chamber 70.

The second alternative is introduction of fluidizing gas from the blower 30 in a gas burner 76, for producing the non-aggressive, substantially oxygen-free gas from the atmospheric air through the elimination of oxygen from the atmospheric air through the combustion of the gas which fluidizing gas is cooled by a heat exchanger 82 after which the fluidization gas 86 is introduced into the gas plenum chamber 70.

The third alternative is introduction of fluidization gas in a combustion engine 78 for producing the non-aggressive, substantially oxygen-free gas from the atmospheric air through the elimination of oxygen from the atmospheric air through the combustion of the gas wherein the exhaust gas is cooled by a heat exchanger 82 before entering the fluidization gas blower 30. The fluidizing gas 86 is then introduced into the gas plenum chamber 70.

In a fourth alternative the fluidization gas comprises an inert gas, such as argon, nitrogen, carbondioxide, or the like or any
combination thereof.

In a fifth alternative the fluidizing gas comprises steam or alternatively air, which has been pretreated as mentioned above in accordance with the first, second and/or third alternative, thereby providing pretreated air containing a small amount of oxygen.

In a further alternative the inert gas is used to delute the fluidization gas or recirculated flue gas (not shown in the drawings) in order to provide a non-aggressive, substantially oxygen-free gas for introduction in a fluid-bed reactor according to the invention.

In fig. 3, a second embodiment of a combustion reactor system is shown comprising a fluid-bed combustion reactor 110' of a structure similar to the structure of the fluid-bed combustion reactor 10 described above with reference to fig. 1. No specific discussion of the fluid-bed combustion reactor 10' is presented, as reference is made to the above discussion of the fluid-bed combustion reactor 10 of the above described first and presently preferred embodiment of the fluid-bed combustion reactor system according to the present invention. Reference is also made to European patent No. 0 332 360 and US patent No. 5 014 652 which is further incorporated in the present specification by reference as the above European patent and the above US patent describe fluid-bed combustion reactor systems similar to the fluid-bed combustion reactor 10'. The fluid-bed combustion reactor system in fig. 3 further comprises a cyclone 38' similar to the above described cyclone 38 and a convection section 90, communicating with the cyclone 38' and further communicating with a steam drum 92 in a fluid-bed combustion reactor system of a structure similar to the structure of the fluid-bed combustion reactor system described in US patent No. 5 273 000 to which reference is made and which is hereby incorporated in the present specification by reference.

Like the above described first embodiment of the fluid-bed combustion reactor system shown in fig. 1, the fluid-bed reactor 10' comprises a particle heat exchanger 36' constituting a two-section heat exchanger. The two sections are designated the reference numerals 94 and 96, respectively, and are provided with individual downcomers 50 and 50', respectively, similar to the downcomer 50 of the above described particle heat exchanger 36 of the fluid-bed reactor 10. Within the sections 94 and 96, individual super heating surfaces 98 and 100, respectively, are provided communicating with the above described steam
drum 92. The super heating surface 100 of the section 96 further communicates with a steam turbine 102 through an inlet 104. The outlet of the steam turbine 102 is designated the reference numeral 106 and communicates with a section of the convection section 90 described above. The steam turbine 102 powers an electric generator (not shown in the drawings) or a different type of load.

A steam extraction 108 of the steam turbine 102 is provided serving the purpose of extracting a fluidizing gas for the sections 94 and 96 of the particle heat exchanger 36′ constituting non-aggressive and oxygen-free fluidizing gas. The steam extracted from the steam turbine 102 through the steam extraction conduct 108 is directed through two valves 116 and 118 for controlling the flow rate of steam to the sections 94 and 96, respectively, of the particle heat exchanger 36′. In fig. 3, an alternative technique of fluidizing the fluid-bed heat exchanger sections 94 and 96 of the particle heat exchanger 36′ is also illustrated as a conduct 114 is shown for the supply of a mixture of gas and atmospheric air to the sections 94 and 96 of the particle heat exchangers 36′. The mixture of gas and atmospheric air is produced by means of a compressor 115 and a mixing chamber 117, and the mixture is combusted within the sections 94 and 96 of the particle heat exchanger 36′ for the production of non-aggressive, substantially oxygen-free fluidizing gases. The fluid-bed reactor 10′ is provided with a bottom particulate material discharge outlet 12′.

In fig. 4, a third embodiment of a combustion reactor system according to the present invention is shown constituting a pressurized fluid-bed combustion reactor system including a pressurized fluid-bed heat exchanger according to the present invention. The pressurized fluid-bed combustion reactor system is designated the reference numeral 110 and is contained within the pressure vessel 120 and further comprises a particulate fluid-bed heat exchanger 136. The fluid-bed combustion reactor 110 and the particulate heat exchanger 136 are basically of structures similar to the above described structures of the first and second embodiments of the fluid-bed combustion reactor systems described above with reference to figs. 1 and 3, respectively. Thus, the fluid-bed combustion reactor 110 also comprises a cyclone 138, the exhaust duct of which is designated the reference numeral 140 and communicates with a gas turbine 142 through a dust filter 144. The gas turbine 142 powers a compressor 145 for pressurizing the pressure vessel
120 and also powers an electric generator 146. The outlet of the gas
turbine 142 is connected to a waste heat boiler 148 including a heating
surface connected to a steam turbine 150 which is also connected to the
particulate heat exchanger 136 through a steam conduct 152. The steam
turbine 150 also powers an electric generator 154 and is connected to a
heating surface 156 within the circuit also including the heating
surface of the waste heat boiler 148. The steam turbine 150 is further
provided with an outlet for generating the fluidizing gas for fluidizing
the fluid-bed particulate heat exchanger 136 of the fluid-bed reactor
110. A make-up water supply conduit 162 is also provided. The fluidizing
gas for fluidizing the fluid-bed particulate heat exchanger 156 is
conducted through a conduct 158 in which a valve 160 is provided for
controlling the flow rate of the steam constituting the fluidizing gas.
The fluid-bed reactor 110 is provided with a bottom particulate material
discharge outlet 112.

In fig. 5, a further and fourth embodiment of a fluid-bed heat
exchanger according to the present invention is shown constituting a
sectional fluid-bed heat exchanger similar to the fluid-bed heat
exchanger disclosed in US patent No. 5 273 000 to which reference is
made and which is hereby incorporated in the present specification by
reference. The sectional fluid-bed heat exchanger is designated the
reference numeral 236 and comprises a total of four sections 236',
236'', 236''' and 236'''''. Each section is provided with a bottom
fluidizing gas inlet 238', 238'', 238''' and 238''''', respectively, for
the supply of fluidizing gas constituting steam or alternatively any
other appropriate, non-aggressive, substance-free gas for
fluidizing the particulate material supplied to the sectioned fluid-bed
heat exchanger, 36, through a particulate material inlet 240 which is
provided at a right hand wall of the sectional fluid-bed heat exchanger
236. The particulate material supplied to the sectional fluid-bed heat
exchanger 236 is caused to be shifted from the first section 236'
further to the second section 236'' and further to the third section
236''' and finally to the fourth section 236''''' from which fourth
section 236''''' the particulate material is returned to the reactor
chamber (not shown in the drawings) through an outlet 244 causing
cooling of the particulate material by heat transferring to heat
transfer media carry through respective heating surfaces 242'', 242'''
and 242''''' of the sections 236'', 236''' and 236''''', respectively.
In fig. 6, a further or fifth embodiment of a fluid-bed combustion reactor system is shown comprising a fluid-bed reactor 210 communicating with a cyclone 238. The fluid-bed reactor 210 and the cyclone 238 are basically of structures similar to the structures of the fluid-bed reactor 10 and the cyclone 38 describe above with reference to fig. 1. however, the fluid-bed reactor 210 differs from the above described fluid-bed reactor 10 in that the fluid-bed particulate heat exchanger 36 of the fluid-bed reactor system shown in fig. 1 is substituted by a sectional non-fluidized heat exchanger 250. The sectional, non-fluidized heat exchanger 250 comprises a total of three sections 250', 250'' and 250''' each including a first heating surface 252', 252'' and 252''', respectively, and a second heating surface 254', 254'' and 254''' included within a respective downcomer 260', 260'' and 260''' of each of the sections 250', 250'' and 250''', respectively. Each downcomer is provided with a respective particulate flow control designated the reference numerals 264', 264'' and 264'''', respectively. Like the above described first, second and third embodiments of the fluid-bed reactors, 10, 10' and 110, respectively described with reference to figs. 1, 3 and 4, respectively, the fluid-bed reactor 210 is provided with a bottom particulate material outtake 212.

It is contemplated that the problems relating to corrosion and depositions associated with conventional fluidized heat exchangers associated with the exhaust gas duct of a fluid-bed reactor are eliminated by the non-fluidized heat exchanger provided within the downcomer of the fluid-bed reactor of the fluid-bed combustion reactor system shown in fig. 6, as any oxygen present within the exhaust gas conducted through the downcomer is reduced by the presence of carbon within the particulate material and is consequently prevented from causing on the one hand the formation of deposits on the heat exchanger and on the other hand the corrosion of the heat exchanger.

Although the present invention has been described above with reference to specific and presently preferred embodiments of the present invention, the present invention is by no means to be construed limited to the above described embodiments as first of all the above described embodiments may be combined in numerous ways, furthermore the above described embodiments may be modified in numerous ways as will be evident to a person having ordinary skill in the art in accordance with techniques well known in the art per se without departing from the scope.
and spirit of the present invention as defined in the appending patent claims.
PATENT CLAIMS

1. A fluid-bed heat exchanger of a fluid-bed combustion reactor system and for establishing heat transfer from heated particulate material fluidized within said fluid-bed heat exchanger to heat transfer means contained within said fluid-bed heat exchanger and internally carrying a heat-transfer medium, said fluid-bed heat exchanger comprising gas inlet means for the introduction of a gas for the fluidization of said particulate material by means of a non-aggressive, substantially oxygen-free gas.

2. The fluid-bed heat exchanger according to claim 1, said non-aggressive, substantially oxygen-free gas being generated through the combustion internally within said fluid-bed heat exchanger of a combustible gas input to said fluid-bed heat exchanger along with atmospheric air through said gas inlet means.

3. The fluid-bed heat exchanger according to any of the claims 1 or 2, said fluid-bed heat exchanger comprising a combustion means for producing said non-aggressive, substantially oxygen-free gas from the atmospheric air through the elimination of oxygen from the atmospheric air through the combustion of fuel within said combustion means.

4. The fluid-bed heat exchanger according to any of the claims 1-3, said gas inlet means communicating with an exhaust duct of said fluid-bed combustion reactor for procuding said non-aggressive, substantially oxygen-free gas from low oxygen content exhaust gas of said fluid-bed combustion reactor.

5. The fluid-bed heat exchanger according to any of the claims 1-4, the content of oxygen of said non-aggressive, substantially oxygen-free gas being less than 5% by volume, such as less than 2.5% by volume, preferably approx. 0% by volume.

6. The fluid-bed heat exchanger according to any of the claims 1-5, said gas inlet means communicating with an inert gas reservoir for the supply of an inert gas, such as argon, nitrogen, carbon dioxide or the like or any combination thereof to said fluid-bed heat exchanger.
constituting said non-aggressive, substantially oxygen-free gas.

7. The fluid-bed heat exchanger according to any of the claims 1-6, said gas inlet means communicating with a steam supply for the supply of steam to said fluid-bed heat exchanger constituting said non-aggressive, substantially oxygen-free gas.

8. The fluid-bed heat exchanger according to any of the claims 1-7, said fluid-bed heat exchanger being a pressurized or alternatively a non-pressurized fluid-bed heat exchanger.

9. The fluid-bed heat exchanger according to any of the claims 1-8, said heat transfer medium being water, steam, Na or K.

10. The fluid-bed heat exchanger according to any of the claims 1-9, said fluid-bed heat exchanger constituting an upwards open vessel with a generally closed bottom wall and side walls, said gas inlet means being provided at said bottom wall of said upwards open vessel, and said fluid-bed heat exchanger further comprising at least one opening in the bottom wall for the discharge of particulate material from said fluid-bed heat exchanger.

11. A fluid-bed combustion reactor system comprising a vertical reactor chamber including a reactor chamber lower portion, a reactor chamber upper portion and an exhaust duct at said reactor chamber upper portion for the withdrawal of exhaust gas and particulate material from said reactor chamber, and a fluid-bed heat exchanger for establishing heat transfer from particulate material transferred thereto from said reactor chamber upper portion through said exhaust duct and fluidized within said fluid-bed heat exchanger to heat transfer means, contained within said fluid-bed heat exchanger and internally carrying a heat-transfer medium, said fluid-bed heat exchanger comprising gas inlet means for the introduction of a gas for the fluidization of said particulate material by means of a non-aggressive, substantially oxygen-free gas.

12. The fluid-bed combustion reactor system, said non-aggressive, substantially oxygen-free gas being generated through the combustion
internally within said fluid-bed heat exchanger of a combustible gas input to said fluid-bed heat exchanger along with atmospheric air through said gas inlet means.

13. The fluid-bed combustion reactor system according to any of the claims 11 or 12, said fluid-bed heat exchanger comprising a combustion means for producing said non-aggressive, substantially oxygen-free gas from the atmospheric air through the elimination of oxygen from the atmospheric air through the combustion of fuel within said combustion means.

14. The fluid-bed combustion reactor system according to any of the claims 11-13, said gas inlet means communicating with an exhaust duct of said fluid-bed combustion reactor for procuring said non-aggressive, substantially oxygen-free gas from low oxygen content exhaust gas of said fluid-bed combustion reactor.

15. The fluid-bed combustion reactor system according to any of the claims 11-14, the content of oxygen of said non-aggressive, substantially oxygen-free gas being less than 5% by volume, such as less than 2.5% by volume, preferably approx. 0% by volume.

16. The fluid-bed combustion reactor system according to any of the claims 11-15, said gas inlet means communicating with an inert gas reservoir for the supply of an inert gas, such as argon, nitrogen, carbon dioxide or the like or any combination thereof to said fluid-bed heat exchanger constituting said non-aggressive, substantially oxygen-free gas.

17. The fluid-bed combustion reactor system according to any of the claims 11-16, said gas inlet means communicating with a steam supply for the supply of steam to said fluid-bed heat exchanger constituting said non-aggressive, substantially oxygen-free gas.

18. The fluid-bed combustion reactor system according to any of the claims 11-17, said fluid-bed heat exchanger being a pressurized or alternatively a non-pressurized fluid-bed heat exchanger.
19. The fluid-bed combustion reactor system according to any of the claims 11-18, said heat transfer medium being water, steam, Na or K.

20. The fluid-bed combustion reactor system according to any of the claims 11-19, said fluid-bed heat exchanger constituting an upwards open vessel with a generally closed bottom wall and side walls, said gas inlet means being provided at said bottom wall of said upwards open vessel, and said fluid-bed heat exchanger further comprising at least one opening in the bottom wall for the discharge of particulate material from said fluid-bed heat exchanger.

21. The fluid-bed combustion reactor system according to any of the claims 11-20, said substantially vertical reactor chamber comprising a first inlet at the reactor chamber lower portion for the introduction of liquid and/or solid particulate material and a second inlet at a level below the first inlet for the introduction of gas for the fluidization of said particulate material within same reactor chamber.

22. A method for the operation of a fluid-bed heat exchanger for establishing heat transfer from heated particulate material fluidized within said fluid-bed heat exchanger to heat transfer means, contained within said fluid-bed heat exchanger and internally carrying a heat-transfer medium, said method comprising introducing a gas into said fluid-bed heat exchanger by means of gas inlet means for the fluidization of said particulate material by means of a non-aggressive, substantially oxygen-free gas.

23. The method according to claim 22, said non-aggressive, substantially oxygen-free gas being generated through the combustion internally within said fluid-bed heat exchanger of a combustible gas input to said fluid-bed heat exchanger along with atmospheric air through said gas inlet means.

24. The method according to any of the claims 22 or 23, said non-aggressive, substantially oxygen-free gas being produced from the atmospheric air through the elimination of oxygen from the atmospheric air through the combustion of fuel within a combustion means.
25. The method according to any of the claims 22-24, said non-aggressive, substantially oxygen-free gas being produced from said from low oxygen content exhaust gas of said fluid-bed combustion reactor.

26. The method according to any of the claims 22-25, the content of oxygen of said non-aggressive, substantially oxygen-free gas being less than 5% by volume, such as less than 2.5% by volume, preferably approx. 0% by volume.

27. The method according to any of the claims 22-26, said non-aggressive, substantially oxygen-free gas being constituted by an inert gas, such as argon, nitrogen, carbon dioxide or the like or any combination thereof.

28. The method according to any of the claims 22-27, said non-aggressive, substantially oxygen-free gas being constituted by steam supplied from a steam supply.

29. The method according to any of the claims 22-28, said fluid-bed heat exchanger being a pressurized or alternatively a non-pressure fluid-bed heat exchanger.

30. The method according to any of the claims 22-29, said heat transfer medium being water, steam, Na or K.

31. The method according to any of the claims 22-30, said method further comprising the discharge of particulate material from said fluid-bed heat exchanger through at least one opening of said fluid-bed heat exchanger, said fluid-bed heat exchanger constituting an upwards open vessel with a generally closed bottom wall and side walls, said gas inlet means being provided at the bottom wall of said upwards open vessel, and said opening being provided in said bottom wall.

32. A method for the operation of a fluid-bed combustion reactor system, comprising a vertical reactor chamber including a reactor chamber lower portion, a reactor chamber upper portion and an exhaust duct at said reactor chamber upper portion for the withdrawal of exhaust gas and particulate material from said reactor, and a fluid-bed heat
exchanger for establishing heat transfer from particulate material transferred thereto from said reactor chamber upper portion through said exhaust duct and fluidized within said fluid-bed heat exchanger to heat transfer means contained within said fluid-bed heat exchanger and internally carrying a heat-transfer medium, said method comprising introducing a gas into said fluid-bed heat exchanger by means of gas inlet means for the fluidization of said particulate material by means of a non-aggressive, substantially oxygen-free gas.

33. The method according to claim 32, said non-aggressive, substantially oxygen-free gas being generated through the combustion internally within said fluid-bed heat exchanger of a combustible gas input to said fluid-bed heat exchanger along with atmospheric air through said gas inlet means.

34. The method according to any of the claims 32 or 33, said non-aggressive, substantially oxygen-free gas being produced from the atmospheric air through the elimination of oxygen from the atmospheric air through the combustion of fuel within a combustion means.

35. The method according to any of the claims 32-34, said non-aggressive, substantially oxygen-free gas being produced from said from low oxygen content exhaust gas of said fluid-bed combustion reactor.

36. The method according to any of the claims 32-35, the content of oxygen of said non-aggressive, substantially oxygen-free gas being less than 5% by volume, such as less than 2.5% by volume, preferably approx. 0% by volume.

37. The method according to any of the claims 32-36, said non-aggressive, substantially oxygen-free gas being constituted by an inert gas, such as argon, nitrogen, carbon dioxide or the like or any combination thereof.

38. The method according to any of the claims 32-37, said non-aggressive, substantially oxygen-free gas being constituted by steam supplied from a steam supply.
39. The method according to any of the claims 32-38, said fluid-bed heat exchanger being a pressurized or alternatively a non-pressurized fluid-bed heat exchanger.

40. The method according to any of the claims 32-39, said heat transfer medium being water, steam, Na or K.

41. The method according to any of the claims 32-40, said method further comprising the discharge of particulate material from said fluid-bed heat exchanger through at least one opening of said fluid-bed heat exchanger, said fluid-bed heat exchanger constituting an upwards open vessel with a generally closed bottom wall and side walls, said gas inlet means being provided at the bottom wall of said upwards open vessel, and said opening being provided in said bottom wall.

42. A fluid-bed combustion reactor system comprising a vertical reactor chamber including a reactor chamber lower portion, a reactor chamber upper portion and an exhaust duct at said reactor chamber upper portion for the withdrawal of exhaust gas and particulate material from said reactor chamber, and a heat exchanger for establishing heat transfer from particulate material transferred thereto from said reactor chamber upper portion through said exhaust duct to heat transfer means, contained within said heat exchanger and internally carrying a heat-transfer medium, said heat exchanger constituting a section of a downcomer connecting said exhaust duct of said reactor chamber upper portion with said reactor chamber lower portion for the recirculation of at least part of said particulate material withdrawn from said reactor chamber.

43. The fluid-bed combustion reactor system according to claim 42 comprising two or more separate heat exchanger sections, said heat exchanger being a sectional heat exchanger constituting a section of an respective downcomer.

44. The fluid-bed combustion reactor system according to any of the claims 11-18, said heat transfer medium being water, steam, Na or K.

45. A method for the operation of a fluid-bed combustion reactor
system, comprising a vertical reactor chamber including a reactor chamber lower portion, a reactor chamber upper portion and an exhaust duct at said reactor chamber upper portion for the withdrawal of exhaust gas and particulate material from said reactor, and a heat exchanger for establishing heat transfer from particulate material transferred thereto from said reactor chamber upper portion through said exhaust duct to heat transfer means contained within said heat exchanger and internally carrying a heat-transfer medium, said heat exchanger being a sectional heat exchanger constituting a section of a respective downcomer, said method comprising allowing said particulate material to flow down through said downcomer.

46. The method according to claim 45, said heat exchanger being a sectional heat exchanger constituting a section of a respective downcomer.

47. The method according to any of the claims 45 or 46, said heat transfer medium being water, steam, Na or K.
**INTERNATIONAL SEARCH REPORT**

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 F23C11/02 F22B31/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F22B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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see column 4, line 15 - line 22
see claim 15; figures

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

* Special categories of cited documents:
  *A* document defining the general state of the art which is not considered to be of particular relevance  
  *E* earlier document but published on or after the international filing date  
  *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)  
  *O* document referring to an oral disclosure, use, exhibition or other means  
  *P* document published prior to the international filing date but later than the priority date claimed  
  *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention  
  *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone  
  *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art  
  *&* document member of the same patent family

Date of the actual completion of the international search: 6 October 1995

Date of mailing of the international search report: 17.01.96

Name and mailing address of the ISA  
European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax (+31-70) 340-3016  
Authorized officer  
VAN GHEEL, J

Form PCT/ISA/210 (second sheet) (July 1992)
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INTERNATIONAL SEARCH REPORT

Box I  Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. □ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II  Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please see annex

1. □ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. □ As all searchable claims could be searches without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. • No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

   1–41, 44

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

Form PCT-ISA/210 (continuation of first sheet (1)) (July 1992)
1. Claims: 1-41, 44
   Introduction of a non-aggressive substantially oxygen-free gas for the fluidization of said particulate material.

2. Claims: 42, 43, 45-47
   Said heat exchanger constituting a section of a downcomer connecting an exhaust duct of said reactor chamber upper portion with a reactor chamber lower portion for the recirculation of at least part of said particulate material withdrawn from said reactor chamber.
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