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(54) COMPOSITE CIRCULATION FLUIDIZED BED BOILER.

(57) This invention relates to a composite circulation fluidized bed boiler. A fluidized bed portion of the fluidized bed boiler is divided by a partition into a main combustion chamber and a heat recovery chamber, and at least two kinds of air chambers, i.e. an air chamber for providing a large fluidizing speed to a fluidization medium and an air chamber for providing a small fluidizing speed are provided. The combination of air having different fluidization speeds and jetted from these air chambers generates a swirling circulation flow in the fluidization medium inside the main combustion chamber and a circulation flow of the fluidization medium is generated between the main combustion chamber and the heat recovery chamber. Inside the heat recovery chamber, heat recovery of an exhaust gas is made at a free board portion or downstream of the free board portion in an internal circulation fluidized bed boiler for lowering the fluidization medium in the form of the fluidized bed, and after the temperature of the exhaust gas is lowered, the exhaust gas thus cooled is led into a cyclone and the char in a fine particle form collected by the cyclone is returned to the portion immediately above, or into, the lowering moving layer of the fluidization medium in the main combustion chamber and/or the heat recovery chamber. Since the char is returned immediately above or into the lowering moving layer of the fluidization medium, it does not immediately scatter to the free board portion. Accordingly, though it is the fine particles, it sediments and diffuses sufficiently into the fluidized bed so that NOx generated by the combustion of coal or the like inside the layer can be reduced.

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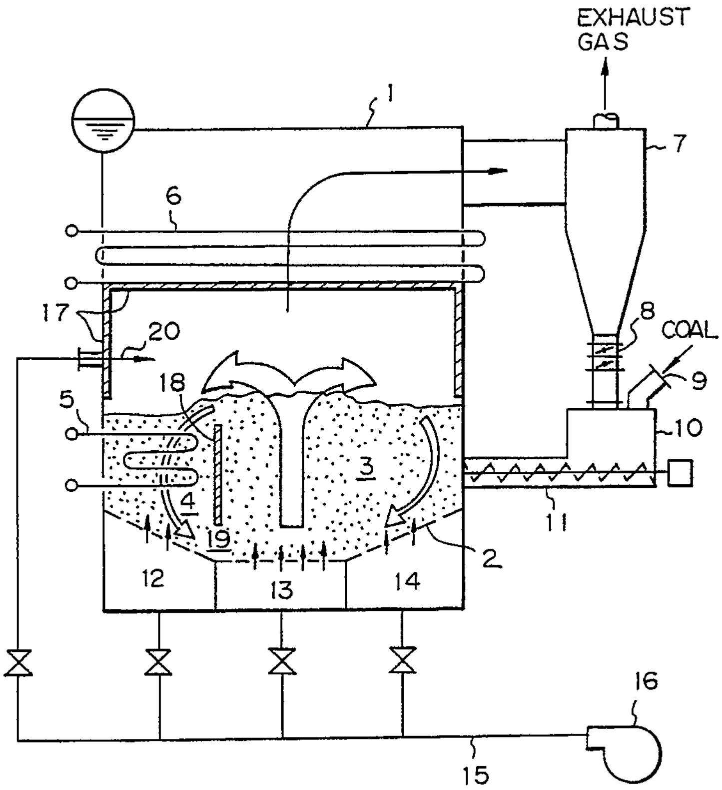
Fig. 1



COMPOSITE RECYCLING TYPE FLUIDIZED BED BOILER

TECHNICAL FIELD

The present invention relates to an internal recycling type fluidized bed boiler in which combustion materials such as various coals, low grade coal, dressing sludge, oil cokes and the like are burnt by a so-called whirling-flow fluidized bed and which recovers thermal energy from a recycling fluidized bed, the interior of a free board and a heat transfer portion provided downstream of the free board portion.

BACKGROUND

Recently, utilization of coal as an energy source in place of petroleum has become more prevalent. In order to widely utilize coal which is inferior in its physical and chemical properties as a fuel to those of petroleum, development of processing and distribution of coal and of technology for promoting the utilization of coal has been in urgent demand. Research and development of a pulverized coal incinerating boiler and the fluidized bed boiler in the field of combustion technology have been positively advanced. With respect to combustion technology such as the above, utilization is restricted to certain kinds of coals in view of the combustion efficiency, requirements of low NOx and low SOx. Also, problems such as the complexity of coal feeding systems and difficulty in controlling load fluctuations have become evident, which problems have been particularly evidenced in small and medium sized boilers.

A fluidized bed boiler is classified into two types as noted below according to the difference in a system wherein arrangement of heat transfer portions and combustion of unburnt particles flown out from the fluidized bed are taken into account.

(1) Non-recycling type fluidized bed boiler (which is also referred to as a conventional type fluidized bed boiler or a bubbling type fluidized bed boiler)

(2) Recycling type fluidized boiler

In a non-recycling type, a heat transfer tube is arranged within a fluidized bed, and heat exchange is carried out by physical contact between the burning fuel and a fluidizing medium with high heat transfer efficiency. On the other hand, in a recycling type, fine unburnt materials, ash and/or a part of the fluidizing medium (recycling solid) are merged into a flow of combustion gas and guided to a heat exchanging portion arranged independently of the combustion chamber where combustion of the unburnt particles is continued and the circulating solid having been heat exchanged is returned to the combustion chamber, the aforesaid title being named since the solid is recycled.

A non-recycling type fluidized bed boiler and a recycling type fluidized bed boiler will be described with reference to Figs. 4 and 5.

Fig. 4 shows a non-recycling type fluidized bed boiler, in which air for fluidization fed under pressure from a blower not shown is injected from an air chamber 74 into a boiler 71 through a diffusion plate 72 to form a fluidized bed 73, and fuel, for example, granular coal is supplied to the fluidized bed 73 for combustion. Heat transfer tubes 76 and 77 are provided in the fluidized bed 73 and an exhaust gas outlet of a free board portion, respectively, to recover thermal energy.

Exhaust gas cooled to a relatively low temperature is guided from an exhaust gas outlet of the free board portion to a convection heat transfer portion 78 to recover thermal energy and discharged outside the system after contained particles are recovered at a cyclone 79. Ash recovered in the convection heat transfer portion is taken out through a tube 81 and discharged outside the system via a tube 82 together with ash taken out from a tube 80, a part thereof being returned to the fluidized bed 73 for re-burning through the air chamber 74 or a fuel inlet 75.

Fig. 5 shows a recycling type fluidized bed boiler, in which air for fluidization fed under pressure from a blower not shown is blown from an air chamber 104 into a furnace 101 through a diffusion plate 102 to fluidize and burn granular coal containing lime as a desulfurizing agent to be supplied into the furnace as needed.

Unlike a non-recycling type fluidized bed boiler, injecting speed of fluidizing air blown through the diffusion plate 102 is higher than the terminal speed of the fluidizing particles, and therefore, mixing of particles and gas is more actively effected and the particles are blown upward together with gas so that a fluidizing layer and a jet-stream layer are formed in that order from the bottom over the whole zone of the combustion furnace. The particles and gas are guided to a cyclone 108 after a small amount of heat exchange is effected at a water cooling furnace wall 107 provided halfway. The combustion gas passed through the cyclone 108 is heat exchanged at a convection heat transfer portion 109 arranged in a flue at the rear portion.

On the other hand, the particles collected at the cyclone 108 are again returned to the combustion chamber via a flowpassage 113, and a part of the particles is guided to an external heat exchanger 115 via a flowpassage 114 for the purpose of controlling the furnace temperature and after being cooled, it is again returned to the combustion chamber while partly discharged outside the system as ash. A feature lies in that the particles are recycled into the combustion chamber in a manner as just mentioned. The recycling particles are mainly limestone supplied as a desulfurizing agent, burnt ash of supplied coal and unburnt ash, etc.

In these fluidized bed boilers, selection of materials to be burnt is widely available in view of characteristics of the combustion system thereof, but some demerits thereof have become noticed.

As the demerits of the bubbling type fluidized bed boiler, there are problems such as those regarding load characteristics, complexity of a fuel supply system and abrasion of heat transfer tubes in the bed, etc.

In order to solve the problems inherent to such matters as above, a recycling type apparatus has become noticed. However, some further factors need to be developed in order to maintain the temperature of a recycling system including a cyclone of a combustion furnace at a proper value. In addition, there still remains a problem in the handling of a recycling solid. With respect to small and medium type boilers, there is a difficulty in making them compact.

DISCLOSURE OF THE INVENTION

After various studies in an attempt to solve the above-described problems, the present inventors have found that it is possible to make a boiler compact, promote combustion efficiency and reduce NOx by the following arrangement. That is in an internal recycling type fluidized bed boiler in which a whirling flow is produced within a fluidized bed due to different speeds in fluidizing air, and the whirling flow is utilized to form a recycling flow of a fluidizing medium relative to a thermal energy recovery chamber, a thermal energy recovery portion such as a vaporizing tube is provided in a free board portion above the fluidized bed or in a portion downstream of the free board portion and exhaust gas is, after being cooled to a low temperature by heat exchange, directed to a cyclone and particles collected at the cyclone are returned to a descending moving bed of the fluidizing medium in the fluidized bed. The inventors further found that selection of coal is not limited to a certain kind because even coal of a high fuel ratio may be completely burnt by the whirling flow, and silica sand can be used as a fluidizing medium together with limestone for reducing SOx whereby all the problems encountered in the conventional coal boilers can be solved.

The characteristics of the present invention are summarized below:

According to the first aspect of the present invention, there is provided an internal recycling type fluidized bed boiler in which a fluidized bed is generally partitioned into a primary combustion chamber and a thermal energy recovery chamber, the primary combustion chamber being accompanied by at least two kinds of air chambers disposed below the primary chambers, i.e., an air chamber for imparting a high fluidizing speed and an air chamber for imparting a low fluidizing speed, these different fluidizing speeds being combined to thereby impart a whirling flow to a fluidizing medium within the primary combustion chamber to form a thermal energy recovery recycling flow of fluidizing medium between the primary combustion chamber and the thermal energy recovery chamber. That is, in the internal recycling fluidized bed provided with an air chamber imparting a low fluidizing speed at a portion below and opposite the thermal energy recovery chamber relative to the primary combustion chamber, exhaust gas is guided into a cyclone and collected particles at the cyclone are returned to a descending moving bed of the primary combustion chamber or the thermal energy recovery chamber.

The collected particles are not always from the cyclone but collected particles from a bag filter or the like can also be returned to the descending moving bed. Returning of collected particles into the descending moving bed causes unburnt composition (char) of the collected particles to be evenly scattered within the fluidized bed so that the whole portion in the bed becomes a reduced atmosphere thereby reducing NOx in a zone ranging from the fluidized bed to the free board portion.

The effect of and advantages in returning the char to the descending moving bed will be discussed hereunder. In case of returning the char to the fluidized bed, the char is immediately scattered into the free board due to the fact that the char consists of fine particles so that there is little dwelling time for the char within the bed, thereby failing to satisfactorily effect combustion of the char itself and function as a catalyst for low NOx. However, in case of returning the char to the descending moving bed, it moves downward and diffuses into the bed whilst it is finely granulated, and therefore, the char is thoroughly moved to reach an area where NOx is generated due to combustion of coal or the like within the bed, whereby NOx is advantageously reduced.

Following two formulas are considered in connection with the reduction of NOx:

$C + 2NO + CO_2 + N_2$ (oxidization reaction of char)

$2CO + 2NO + 2CO_2 + N_2$ (catalyst reaction of char)

The char is participated in any of reactions above. It is considered that the oxidization reactivity and catalyst effect of char exert an influence on the function of reducing the generation of NOx.

According to the second aspect of the present invention, heat transfer tubes are arranged in a free board portion above a fluidized bed or downstream of the free board portion, and recovery of thermal energy is primarily effected by convection heat transfer.

In the past, a convection heat transfer portion has been provided independently of a free board portion. However, in order to make a boiler compact, such a convection heat transfer portion is provided unitarily with a free board portion at an upper part within a free board or downstream of a free board portion while sufficient volume required for secondary combustion in a free board portion is retained. With such an arrangement as outlined above, treatment of dust and recycling of char around a boiler can be facilitated as compared to the prior art. In addition, the temperature of gas entering into a cyclone becomes 250 to 400° C, and therefore, the cyclone need not be provided with castable lining, and the cyclone can be made of steel and be light in weight and miniaturized.

According to the third aspect, a convection heat transfer portion is provided at an upper part within a free board or a furnace wall is constructed to comprise water cooling tubes. In view of such a provision as above, heat insulating material such as refractory material is lined on the convection heat transfer portion and the water cooling furnace wall on the side of the combustion chamber in order to prevent the temperature of the combustion gas within the free board from being lowered due to radiation effect. With the above arrangement, the temperature of combustion gas is maintained so as to be effective in reducing CO or the like.

In the case where a convection heat transfer portion is provided downstream of the free board portion, refractory heat insulating material may be lined only on a water cooling wall constituting the free board portion.

As explained hereinabove, the present invention provides a composite recycling type fluidized bed boiler effecting a combination of three circulative movements, i.e., a whirling flow circulation in the primary combustion chamber, a thermal energy recovering circulative movement of a fluidizing medium recycled between a primary combustion chamber and a thermal energy recovery chamber, and an external recycling (char recycling) for returning unburnt char to a descending moving bed of a fluidizing medium within a primary combustion chamber or a thermal energy recovery chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1, 2 and 3 are schematic views of different types of composite recycling type fluidized bed boilers, respectively, according to the present invention, in which heat transfer tubes such as vaporization tubes are disposed at an upper part within a free board; Fig. 4 is a schematic view of a conventional fluidized bed boiler; Fig. 5 is a schematic view of a conventional recycling type fluidized bed boiler; Fig. 6 is a graph indicating the relationship between an amount of fluidizing air at a lower portion of an inclined partition wall and a recycling amount of a fluidizing medium in a thermal energy recovery chamber; Fig. 7 is a graph indicating the relationship between an amount of diffusing air for a thermal energy recovery chamber and a descending rate of downwardly moving bed; Fig. 8 is a graph generally indicating a mass flow for fluidization and an overall thermal conducting coefficient; Fig. 9 is a graph indicating an amount of diffusing air for a thermal energy recovery chamber and an overall thermal conducting coefficient in an internal recycling type; Fig. 10 is a graph indicating the relationship between a fluidizing mass flow and an abrasion rate of a heat transfer tube; Fig. 11 is a schematic view of a composite recycling type fluidized bed boiler according to the present invention in which a group of heat transfer tubes such as vaporization tubes integrally provided with a free board portion are arranged downstream of the free board portion; Fig. 12 is a sectional view taken along the line A - A of Fig. 11; Fig. 13 is a sectional view along a sectioning line corresponding to the line A - A of Fig. 11 in a composite recycling type fluidized bed boiler designed so that a group of heat transfer tubes such as vaporization tubes integrally provided with a free board portion are disposed downstream of the free board portion and relatively large particles collected at said group of heat transfer tubes are returned to left and right thermal energy recovery chambers disposed on opposite sides of a primary combustion chamber; and Fig. 14 is a view showing an embodiment in which particles containing fine char collected at a cyclone are returned to a carrier such as a conveyor for returning particles collected at said group of heat transfer tubes to the fluidized bed portion.

BEST MODE OF PRACTICING THE INVENTION

The present invention will be schematically explained referring to the drawings.

In Fig. 1, a boiler body 1 is internally provided on the bottom thereof with a diffusion plate 2 for an fluidizing air which is introduced from a fluidizing air introducing tube 15 by means of a blower 16, the diffusion plate 2 having opposite edges arranged to be higher than a central portion of the plate, the bottom of the boiler body being formed as a concave surface.

The fluidizing air fed by the blower 16 is injected upwardly from the air diffusion plate 2 via air chambers 12, 13 and 14. A mass flow of the fluidizing air injected out of the central air chamber 13 is arranged to be enough to form a fluidized bed of a fluidizing medium within the boiler body, that is, in the range of 4 to 20 Gmf, preferably, in the range of 6 to 12 Gmf. A mass flow of the fluidizing air injected out of the air chambers 12 and 14 on the opposite sides is smaller than the former, generally, in the range of 0 to 3 Gmf. It is preferable that air is injected in a mass flow of 0 to 2 Gmf from the air chamber 12 located below the thermal energy recovery chamber 4 and provided with a heat transfer tube 5, and air is injected in a mass flow of 0.5 to 2 Gmf from the air chamber 14 which forms a lower portion of the primary combustion chamber 3.

Since the mass flow of the fluidizing air injected out of the air chamber 13 within the primary combustion chamber 3 is relatively larger than that of the fluidizing air injected out of the air chambers 12 and 14, the air and the fluidizing medium are rapidly moved upward in the portion above the air chamber 13 forming a jet stream within the fluidized bed, and upon passing through the surface of the fluidized bed, they are diffused and the fluidizing medium falls onto the surface of the fluidized bed at the portions above the air chambers 12 and 14.

On the other hand, in the fluidized bed above the air chamber 13, fluidizing medium under gentle fluidization at the opposite sides moves to occupy a space from where the fluidizing medium is moved upward. The fluidizing medium in the fluidized bed above the air chambers 12 and 14 is moved to the central portion, i.e., the portion above the air chamber 13. As a result, a violent upward stream is formed in the central portion in the fluidized bed but a gentle descending moving bed is formed in the peripheral portions.

The thermal energy recovery chamber 4 makes use of the aforesaid descending moving bed. Fig. 8 shows the relationship between an overall thermal conducting coefficient and a fluidizing mass flow in a bubbling system. However, according to the present invention, a large overall thermal conducting coefficient is obtained at a fluidizing mass flow of 1 to 2 Gmf as shown in Fig. 7 without effecting such severe fluidization (generally, 3 to 5 Gmf) as in the bubbling system and sufficient thermal energy recovery can be effected.

A vertical partition wall 18 is provided internally of the fluidized bed at the portion above a boundary between the air chambers 12 and 13, and the heat transfer tube 5 is arranged at the portion above the air chamber 12 to form a thermal energy recovery chamber, that is, internally of the fluidized bed between the back of the partition wall 18 and the water cooling furnace wall. The height of the partition wall 18 is designed to be sufficient for allowing the fluidizing medium to pass from a portion above the air chamber 13 into the thermal energy recovery chamber 4 during operation, and an opening 19 is provided between the partition wall 18 and the air diffusion plate on the bottom so that the fluidizing medium within the thermal energy recovery chamber 4 may be returned into the primary combustion chamber 3. Accordingly, the fluidizing medium diffused above the surface of the fluidized bed after having been violently moved up as a jet stream within the primary combustion chamber moves beyond the partition wall 18 into the thermal energy recovery chamber, and is gradually moved down while being gently fluidized by air blown from the air chamber 12 with heat exchange being effected through the heat transfer tube 5 during its descent.

The recycling amount of the descending fluidizing medium in the thermal energy recovery chamber is dependent on the amount of diffusing air fed from the air chamber 12 to the thermal energy recovery chamber 4 and the amount of fluidizing air fed from the air chamber 13 in the primary combustion chamber. That is, as shown in Fig. 6, the amount G_1 of the fluidizing medium entering into the thermal energy recovery chamber 4 increases as the amount of the fluidizing air blown out of the air chamber 13 increases. Also, as shown in Fig. 7, when the amount of diffusing air fed into the thermal energy recovery chamber 4 is varied in the range of 0 to 1 Gmf, the amount of the fluidizing medium descending in the thermal energy recovery chamber substantially varies proportionally thereto, and is substantially constant if the amount of diffusing air in the thermal energy recovery chamber exceeds 1 Gmf.

The aforesaid constant amount of the fluidizing medium is substantially equal to the fluidizing medium amount G_1 moved into the thermal energy recovery chamber 4, and the amount of fluidizing medium descending in the thermal energy recovery chamber corresponds to G_1. With these two amounts of air being regulated, the descending rate of the fluidizing medium in the thermal energy recovery chamber 4 is controlled.

On the other hand, thermal energy is recovered from the descending fluidizing medium through the heat transfer tube 5. The heat conducting coefficient changes substantially linearly as shown in Fig. 9 when the diffusing amount of air fed into the thermal energy recovery chamber 4 from the air chamber 12 is changed from 0 to 2 Gmf, and therefore, the thermal energy recovery amount and the fluidized bed temperature within the primary combustion chamber 3 can be optionally controlled by regulating the amount of diffusing air.

That is, with the amount of fluidizing air from the air chamber 13 in the primary combustion chamber 3 being kept constant, the fluidizing medium recycling amount increases when the amount of diffusing air within the thermal energy recovery chamber 4 is increased and at the same time the thermal conducting coefficient is increased, whereby the amount of thermal energy recovery is considerably increased as a result of synergistic effect. If an increment of the aforesaid amount of thermal energy recovery is balanced with an increment of the generated thermal energy in the primary combustion chamber, the temperature of the fluidized bed is maintained at constant.

It is said that an abrasion rate of a heat transfer tube in a fluidized bed is proportional to the cube of a fluidizing flow rate. Fig. 10 shows the relationship between a fluidizing mass flow and an abrasion rate. That is, with the amount of diffusing air blown into the thermal energy recovery chamber being kept at 0 to 3 Gmf, preferably, 0 to 2 Gmf, the heat transfer tube encounters an extremely small degree of abrasion and thus durability can be enhanced.

On the other hand, coal as fuel is supplied to the initiating portion of the descending moving bed within the primary combustion chamber 3. Therefore, coal supplied as above is whirled and circulated within the high temperature fluidized bed, and even coal of a high fuel ratio can be completely burnt. Since high load combustion is made available, a boiler can be miniaturized, and in addition, there is no restriction on the kind of coals which may be selected so that the use of boilers is promoted.

Exhaust gas is discharged from the boiler and guided to the cyclone 7. On the other hand, particles collected at the cyclone pass through a double damper 8 disposed at a lower portion in the boiler shown in Fig. 1 and are introduced into a hopper 10 together with coal simultaneously supplied, with the both being mixed by a screw feeder 11 and fed to the descending moving bed of the primary combustion chamber thereby contributing to the incineration of unburnt substance (char) in the collected particles and to the reduction of NOx. It is noted that particles collected at the cyclone will, of course, be mixed with coal due to whirling and circulation in the primary combustion chamber even if they are not preliminarily mixed in advance with the particles and coal being independently transported to a portion before the primary combustion chamber and fed into the descending moving bed of the primary combustion chamber.

On the other hand, in an upper portion of the free board, a convection heat transfer surface means 6 is provided to effect heat recovery as an economizer and a vaporizing tube. A heat insulating material 17 such as a refractory material is mounted as required on the lower portion of the convection heat transfer surface means 6 and the water cooling furnace wall on the side of the combustion chamber in order to maintain the combustion temperature in the free board at a constant temperature, preferably, 900 °C. In the case of the convection heat transfer surface means, each heat transfer tube near the free board portion is mounted so as to be wound with a heat insulating material. Needless to say, a pitch of the heat transfer tube is taken into consideration so as not to impede a flow passage of the exhaust gas.

Due to the provision of the heat insulating material 17 as described above, it is possible to maintain the temperature of the lower portion of the free board portion at a high temperature so that the provision is effective to reduce CO by air blown from an air blow opening 20 for a secondary combustion in the free board portion.

Fig. 2 shows a further embodiment of the present invention.

Basically, this embodiment is similar, with respect to its construction, to the boiler shown in Fig. 1 and performs an operation similar thereto. What is largely different in this embodiment from the previous embodiment is that a lower portion of a partition wall 38 between a primary combustion chamber 23 and a thermal energy recovery chamber 24 is inclined so as to interrupt, in the primary combustion chamber, an upward flow from an air chamber 33 under a high fluidizing rate and to turn the flow toward an air chamber 34 under a low fluidizing rate, the angle of inclination being 10 to 60 degrees relative to the horizon, preferably 25 to 45 degrees. The horizontal length ℓ of the inclined portion of the partition wall projected onto the furnace bottom is arranged to be 1/6 to 1/2, preferably 1/4 to 1/2 of the horizontal length L of the opposing furnace bottom.

The fluidized bed at the bottom of a boiler body 21 is divided by the partition wall 38 into the thermal energy recovery chamber 24 and the primary combustion chamber 23, and an air diffusion plate 22 for fluidization is provided at the bottom of the primary combustion chamber 23.

The central portion of the diffusion plate 22 is arranged to be low and the side opposite the thermal energy recovery chamber to be high. Two kinds of air chambers 33 and 34 are provided below the diffusion plate 22.

A mass flow of fluidizing air injected out of the central air chamber 33 is arranged to be enough for causing a fluidizing medium within the primary combustion chamber to form a fluidizing bed, that is, in the range of 4 to 20 Gmf, preferably, in the range of 6 to 12 Gmf, whereas a mass flow of fluidizing air injected out of the air chamber 34 is arranged to be smaller than the former, in the range of 0 to 3 Gmf so that the fluidizing medium above the air chamber 34 is not accompanied by violent up-and-down movement but forms a descending moving bed in a weak fluidizing state. This moving bed is spread at the lower portion thereof to reach the upper portion of the air chamber 33 and therefore encounters an injecting flow of fluidizing air having a large mass flow from the air chamber 33 and is blown up. Thus, a part of the fluidizing medium at the lower portion of the moving bed is removed, and therefore, the moving bed is moved down due to its own weight. On the other hand, the fluidizing medium blown up by the injecting flow of the fluidizing air from the air chamber 33 impinges upon the inclined partition wall 38 and is reversed and deflected, a majority of which falls on the upper portion of the moving bed to supplement the fluidizing medium of the moving bed moved downwardly. As the result of the continuous operation as described above, at the portion above the air chamber 34, a slowly descending moving bed is formed and as a whole, the fluidizing medium within the primary combustion chamber 23 is caused to form a whirling flow. On the other hand, a part of the fluidizing medium blown up by the fluidizing air from the air chamber 33, reversed and deflected by the inclined partition wall 38 moves beyond the inclined partition wall 38 and enters into the thermal energy recovery chamber 24. The fluidizing medium moved into the thermal energy recovery chamber 24 forms a gentle descending moving bed by the air blown by an air diffuser 32.

In the case where the descending rate is slow, the fluidizing medium moved into the thermal energy recovery chamber forms an angle of repose at the upper portion of the thermal energy recovery chamber, and a surplus portion thereof falls from the upper portion of the inclined partition wall 38 to the primary combustion chamber.

Within the thermal energy recovery chamber, the fluidizing medium is subjected to heat exchange through the heat transfer tube 25 while moving down slowly, after which the medium is returned from the opening 39 into the primary combustion chamber.

The descending recycling amount and the thermal energy recovery amount of the fluidizing medium within the thermal energy recovery chamber are controlled by the amount of diffusing air blown into the thermal energy recovery chamber in a way similar to that of the embodiment shown in Fig. 1. In the case of the boiler shown in Fig. 2, controlling is effected by the amount of air blown from the air diffuser 32, and the mass flow thereof is arranged to be in the range of 0 to 3 Gmf, preferably 0 to 2 Gmf.

Coal as fuel is supplied to the portion above the air chamber 34 wherein the descending moving bed is formed within the primary combustion chamber 23 whereby the coal is whirled and circulated within the fluidized bed of the primary combustion chamber and incinerated under excellent conditions of combustibility.

On the other hand, exhaust gas is directed to a cyclone 27 after being discharged from the boiler. The particles collected at the cyclone 27 pass through a double damper 28 and are introduced into a hopper 30 together with coal parallelly supplied. They are mixed and supplied by a screw feeder 31 to the descending moving bed in the primary combustion chamber 23, that is, a portion above the air chamber 34, to contribute to the combustion of unburnt substance (char) in the collected particles and reduction in NOx.

Although not particularly shown, the particles collected at the cyclone 27 may be supplied independently of coal, unlike the supply device shown in Fig. 2, and the particles and coal may be fed by an airborne means instead of the screw feeder.

On the other hand, in the upper portion of the free board, a convection heat transfer surface means 26 is provided to effect thermal energy recovering. A heat insulating material 37 such as a refractory material is mounted on the lower portion of the convection heat transfer surface means 26 and side of the water cooling furnace wall opposing the combustion chamber as required in order to maintain the combustion temperature of the free board at a constant temperature, preferably 900° C, and an air inlet 40 is provided for the purpose of secondary combustion to effectively reduce CO or the like.

Fig. 3 shows a still another embodiment of the present invention. Basically, it is constructed unitarily to incorporate a thermal energy recovery chamber shown in Fig. 2 symmetrically opposed in positions. As a result, an air chamber 53 having a small mass flow of blown air is positioned centrally, and air chambers having a large mass flow are arranged as chambers 52 and 54. Therefore the flowing stream of fluidizing medium caused by air blown out of the air chambers 52 and 54 is reversed by inclined partition walls 58 and 58' and falls on the central portion. The flow is thence formed into a descending moving bed and reaches the portion above the air chamber 53, where it is divided into left and right portions, which are again blown up. Accordingly, two symmetrical whirling flows are present in the fluidized bed within the primary combustion chamber.

The coal and the particles collected at the cyclone are supplied to the central descending moving bed.

In Fig. 3, the supply position is indicated by a marking * within the primary combustion chamber, and the supplying direction is vertical relative to the paper surface. While the particles collected at the cyclone and coal are mixed and supplied by a screw feeder 51 in an embodiment shown in Fig. 3, it is to be noted that they may be supplied independently from each other, though not shown, or an airborne supply means may be employed.

On the other hand, when the flow of the fluidizing medium caused by air blown out of the air chambers 52 and 53 is deflected at the inclined partition walls 58 and 58', a part thereof moves over the partition walls to enter into thermal energy recovery chambers 44 and 44'.

The descending recycling amount of the fluidizing medium within the thermal energy recovery chambers is controlled by the amount of diffusing air introduced from air diffusers 60 and 60' in a manner similar to that of the diffuser shown in Fig. 2.

The fluidizing medium, after being heat exchanged by heat transfer tubes 45 and 45', passes through openings 59 and 59' to return into the primary combustion chamber.

A convection heat transfer surface means 46 is provided at a portion above the free board portion to effect heat exchange. A heat insulating material 57 such as a refractory material is mounted as required on the convection heat transfer surface means 46 and the side of the water cooling furnace wall opposing the combustion chamber in order to maintain the combustion temperature in the free board at a constant temperature, preferably, 900 °C, and an air inlet 61 is provided for the purpose of secondary combustion to effectively reduce CO or the like.

Another embodiment will be described hereinafter with reference to Figs. 11 to 14, in which thermal energy recovery from exhaust gas is carried out by a group of heat transfer tubes provided downstream of the free board portion and integrally with the free board portion.

Fig. 11 is a longitudinal sectional view of a composite recycling type fluidized bed boiler showing one embodiment of the present invention in which heat recovery from exhaust gas is carried out by a group of heat transfer tubes provided downstream of the free board portion and integrally with the free board portion. Fig. 12 is a sectional view taken along the line A - A of Fig. 11. In Figs. 11 and 12, reference numeral 201 designates a boiler body, 202 an air diffusion nozzle for fluidization, 203 a primary combustion chamber, 204 and 204' thermal energy recovery chambers, 205 and 205' heat transfer tubes, 207 a cyclone, 208 a rotary valve, 209 a fuel supply tube, 210 a hopper, 211 a screw feeder for supplying fuel, 212, 213 and 214 air chambers, 218 and 218' partition walls, 219 and 219' openings at the lower portion of the thermal energy recovery chamber, 220 a secondary air introducing tube, 229 an outlet for exhaust gas, 230 a steam drum, 231 a water drum, 232 a convection heat transfer chamber, 233, 234 and 235 partition walls in the convection heat transfer chamber, 236 vaporization tubes, 237 a water pipe wall, 238 a bottom of the convection heat transfer chamber, 239 a screw conveyor, 240 an exhaust pipe for the convection heat transfer chamber, and 247, 247', 243 and 243' air diffusers of the type different from those shown in Figs. 1 and 2.

The functions of the primary combustion chamber and the thermal energy recovery chambers etc. shown in Figs. 11 and 12 are exactly the same as those explained in connection with Fig. 3, but the boiler shown in Figs. 11 and 12 is different from that shown in Fig. 3 in that a group of heat transfer tubes for recovering thermal energy from exhaust gas are not provided in the free board portion but the convection heat transfer portion integral with the free board portion is provided downstream of the free board portion.

That is, exhaust gas discharged out of the exhaust gas outlet 229 in the free board portion is introduced into the convection heat transfer chamber 232 having a group of vaporization tubes provided between the steam drum 330 and the water drum 231, heat-exchanged with water in the group of vaporization tubes during flowing toward the downstream of the convection chamber in the direction as indicated by the arrow due to the presence of the partition walls arranged within the convection heat transfer chamber, cooled to 250 to 400 °C and thereafter introduced into the cyclone 207 via the exhaust pipe 240 so that fine particles containing char are collected at the cyclone and the gas is then discharged into the atmosphere. The fine particles containing the char collected at the cyclone are returned via the rotary valve 208 and a charging opening to a portion directly above the descending moving bed of the primary combustion chamber 203, the charging opening being the same for fuel such as coal supplied to the boiler via the charging opening 209, the hopper 210 and the screw feeder 211.

On the other hand, the fluidizing medium having a relatively large grain size separated in the convection heat transfer portion 232 and grains containing desulfurizer and char are gathered to a V-shaped bottom at the lower portion of the convection heat transfer portion and then returned by the screw conveyor 239 to the portion directly above the descending moving bed on the side opposite the fuel supply side in the primary combustion chamber.

In the case where the convection heat transfer portion is provided downstream of the free board portion as shown in Figs. 11 and 12, the secondary air is blown in a reverse direction to the flowing direction of the exhaust gas flowing into the convection heat transfer portion from the free board portion thereby causing a whirling flow in the free board portion so that oxygen and exhaust gas are efficiently stirred and mixed to effectively promote reduction of CO.

Another embodiment will be described with reference to Fig. 13.

Fig. 13 is a sectional view corresponding to Fig. 12, and reference numerals in Fig. 13 are the same in meaning as those shown in Fig. 12 except that 238' designates a V-shaped bottom of the convection heat transfer portion and 239' designates a screw conveyor.

This embodiment is different from the boilers shown in Figs. 11 and 12 only in that two V-shaped bottoms 238 and 238' (W-shaped bottoms) are provided at the lower portion of the convection heat transfer chamber, and that particles containing relatively large char collected at the V-shaped bottoms 238 and 238' are returned by screw conveyors 239 and 239' to the portion directly above the descending moving beds 204 and 204' of the fluidizing medium in the thermal energy recovery chambers provided at opposite sides of the combustion chamber.

Fig. 14 shows still another embodiment of the present invention.

Reference numerals used in Fig. 14 are the same in meaning as those used in Fig. 11 except that the reference numeral 241 designates a conduit. The embodiment shown in Fig. 14 is merely different from that of Fig. 11 in that fine particles containing char collected at the cyclone 207 are directed to the screw feeder 239 at the lower portion of the convection heat transfer portion 232 by the conduit 241 and then returned together with the particles containing a relatively large char collected at the convection heat transfer portion to the portion directly above the descending moving bed in the primary combustion chamber.

Claims

1. In an internal recycling type fluidized bed boiler in which a fluidized bed portion of the boiler is divided by a partition into a primary combustion chamber and a thermal energy recovery chamber and at least two kinds of air chambers are provided at a portion below the primary combustion chamber, one being an air chamber for imparting a high fluidizing speed to a fluidizing medium and the other being an air chamber for imparting a low fluidizing speed to a fluidizing medium thereby providing a whirling and circulating flow to the fluidizing medium within the primary combustion chamber by a combination of air flows having different fluidizing speeds injected out of these air chambers to form a recycling flow of the fluidizing medium between the primary combustion chamber and the thermal energy recovery chamber, a composite recycling type fluidized bed boiler characterized in that thermal energy recovery from exhaust gas is carried out, the exhaust gas at a boiler outlet is cooled and thereafter guided to a cyclone and particles collected at said cyclone are returned to said primary combustion chamber or said thermal energy recovery chamber wherein a returning opening thereof is arranged directly above or in a descending moving bed having a low fluidizing speed within the fluidized bed.

2. A composite recycling type fluidized bed boiler as claimed in Claim 1 characterized in that a partition wall separating said primary combustion chamber and said thermal energy recovery chamber is positioned and inclined so as to interrupt an upward flow of fluidizing air injected out of and upwardly of an air injecting portion having a large mass flow in the primary combustion chamber and to reverse and deflect said fluidizing air to a portion above an air injecting portion having a small mass flow.

3. A composite recycling type fluidized bed boiler as claimed in Claim 1 or 2 characterized in that a desulfurizer is supplied to the descending moving bed in the primary combustion chamber.

4. A composite recycling type fluidized bed boiler as claimed in Claim 1, 2 or 3 characterized in that exhaust gas is guided to the cyclone after said exhaust gas has been cooled to 250 °C to 400 °C.

5. A composite recycling type fluidized bed boiler as claimed in Claim 1, 2, 3 or 4, wherein thermal energy recovery from the exhaust gas is effected by a group of heat transfer tubes provided in a free board portion above the fluidized bed.

6. A composite recycling type fluidized bed boiler as claimed in Claim 1, 2, 3 or 4, wherein thermal energy recovery from the exhaust gas is effected by a group of heat transfer tubes

provided integrally with a free board portion and downstream of the free board portion.

7. A composite recycling type fluidized bed boiler as claimed in Claim 6 characterized in that fluidizing medium having a relatively large grain size, desulfurizer and char particles collected at portions of a group of heat transfer tubes provided integrally with the free board portion and downstream of the free board portion, are returned by a transporting means such as a screw conveyor to a portion directly above the descending moving bed of the fluidized bed or into the descending moving bed in the primary combustion chamber.

8. A composite recycling type fluidized bed boiler as claimed in Claim 6 characterized in that a fluidizing medium having a relatively large grain size, desulfurizer and char particles collected at portions of a group of heat transfer tubes provided integrally with the free board portion and downstream of the free board portion, are returned by a transporting means such as a screw conveyor to a portion directly above the descending moving bed of the fluidizing medium or into the descending moving bed in the thermal energy recovery chamber.

9. A composite recycling type fluidized bed boiler as claimed in Claim 8 characterized in that fluidizing medium having a relatively large grain size, desulfurizer and char particles are returned to both the thermal energy recovery chambers provided at left and right sides in the primary combustion chamber.

10. A composite recycling type fluidized bed boiler as claimed in Claim 7, 8 or 9 characterized in that particles containing fine char collected at the cyclone are returned to a transporting means such as a conveyor for returning the particles collected at the portions of the group of heat transfer tubes provided integrally with said free board portion to the fluidized bed portion or the thermal energy recovery portion.

11. A composite recycling type fluidized bed boiler as claimed in any one of Claims 1 to 10 characterized by its construction wherein secondary air is blown in the direction opposite to the flowing direction of the exhaust gas flown from the free board portion to a convection heat transfer portion to thereby produce a whirling flow of the exhaust gas in the free board portion.

12. In an internal recycling type fluidized bed boiler in which a fluidized bed portion of the boiler is divided by a partition into a primary combustion chamber and a thermal energy recovery chamber and at least two kinds of air chambers are provided at a portion below the primary combustion chamber, one being an air chamber for imparting a high fluidizing speed to a fluidizing medium and the other being an air chamber for imparting a low fluidizing speed to a fluidizing medium thereby providing a whirling and circulating flow to the fluidizing medium within the primary combustion chamber by a combination of air flows having different fluidizing speeds injected out of these chambers to form a recycling flow of the fluidizing medium between the primary combustion chamber and the thermal energy recovery chamber, a composite recycling type fluidized bed boiler characterized in that it comprises a convection heat transfer portion provided integrally with and downstream of a free board of the primary combustion chamber, a steam drum is provided at a portion above the free board portion and the convection heat transfer portion, a water drum is provided at a portion below the convection heat transfer portion, a pipe constituting a water pipe wall of the primary combustion chamber is taken out from a portion of said steam drum above the free board, a vaporization tube for cooling exhaust gas and recovering thermal energy is provided between the steam drum and the water drum in the convection heat transfer portion, and particles collected at the convection heat transfer portion are returned to a portion directly above or into a descending moving bed having a small fluidizing speed of the fluidizing medium in the primary combustion chamber or the thermal energy recovery chamber.

13. A composite recycling type fluidized bed boiler as claimed in Claim 12 wherein collected particles are gathered to a V-shaped bottom provided at a portion below the water drum and returned by a screw conveyor arranged in the V-shaped bottom to a portion directly above or into the descending moving bed of the fluidizing medium in the primary combustion chamber or the thermal energy recovery chamber.

14. A composite recycling type fluidized bed boiler as claimed in Claim 12 wherein collected particles are gathered to a W-shaped bottom provided at a portion below the water drum and returned by a screw conveyor arranged in the W-shaped bottom to a portion directly above or into the descending moving bed of the

fluidizing medium in the thermal energy recovery chamber.

Fig. 1

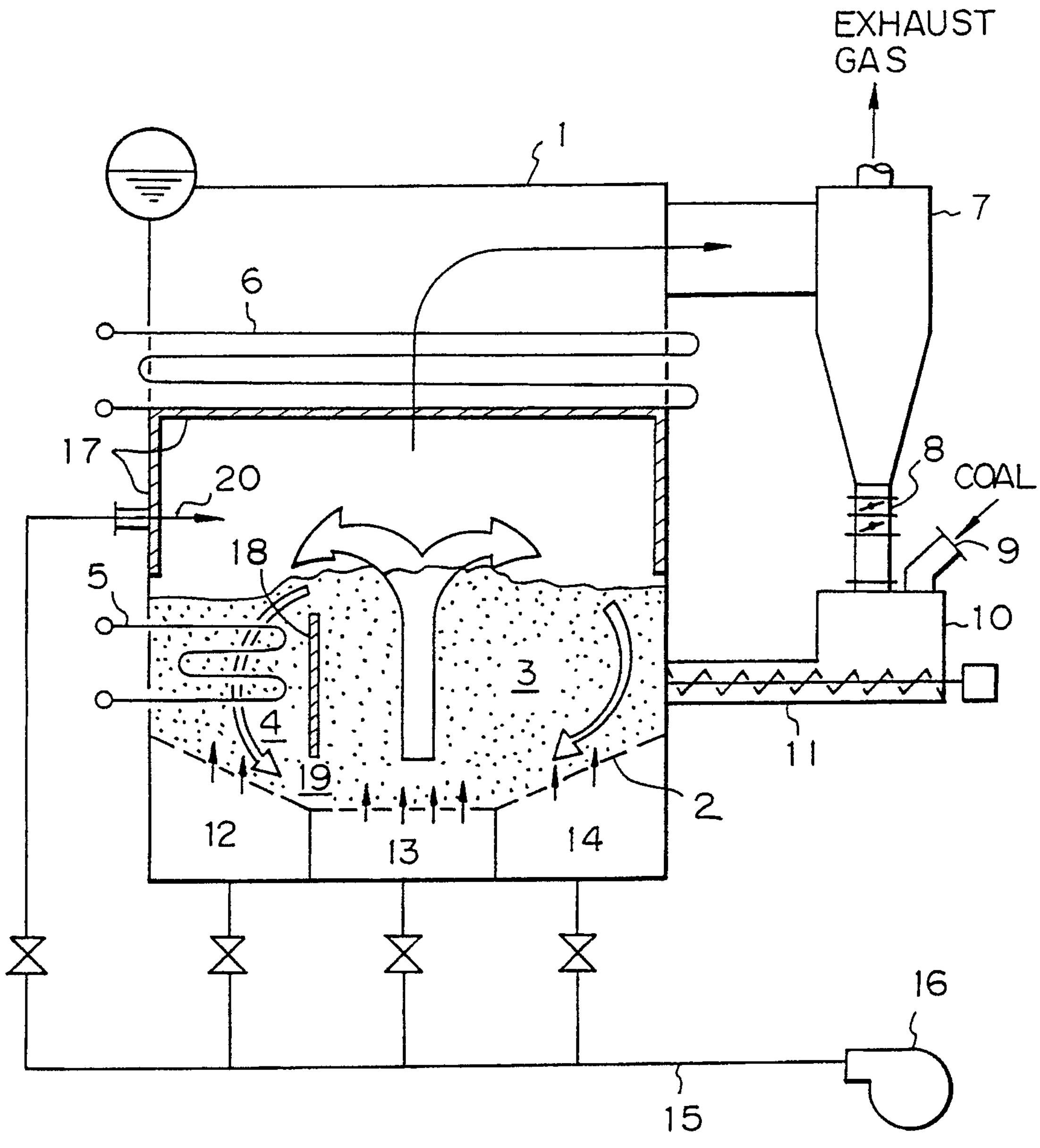
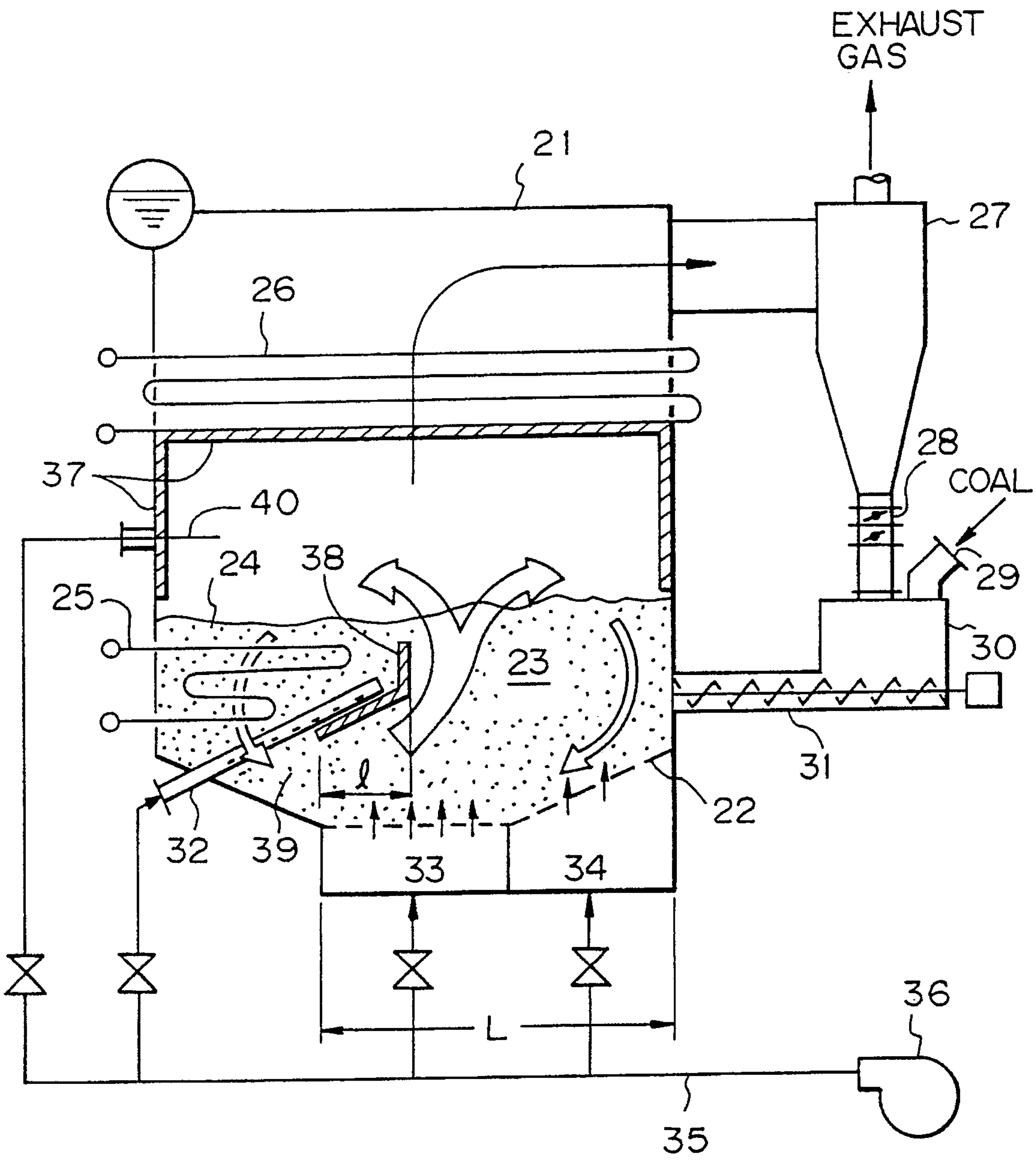


Fig. 2


EXHAUST
GAS
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27
26
28
COAL
37
40
29
24
38
25
23
30
31
22
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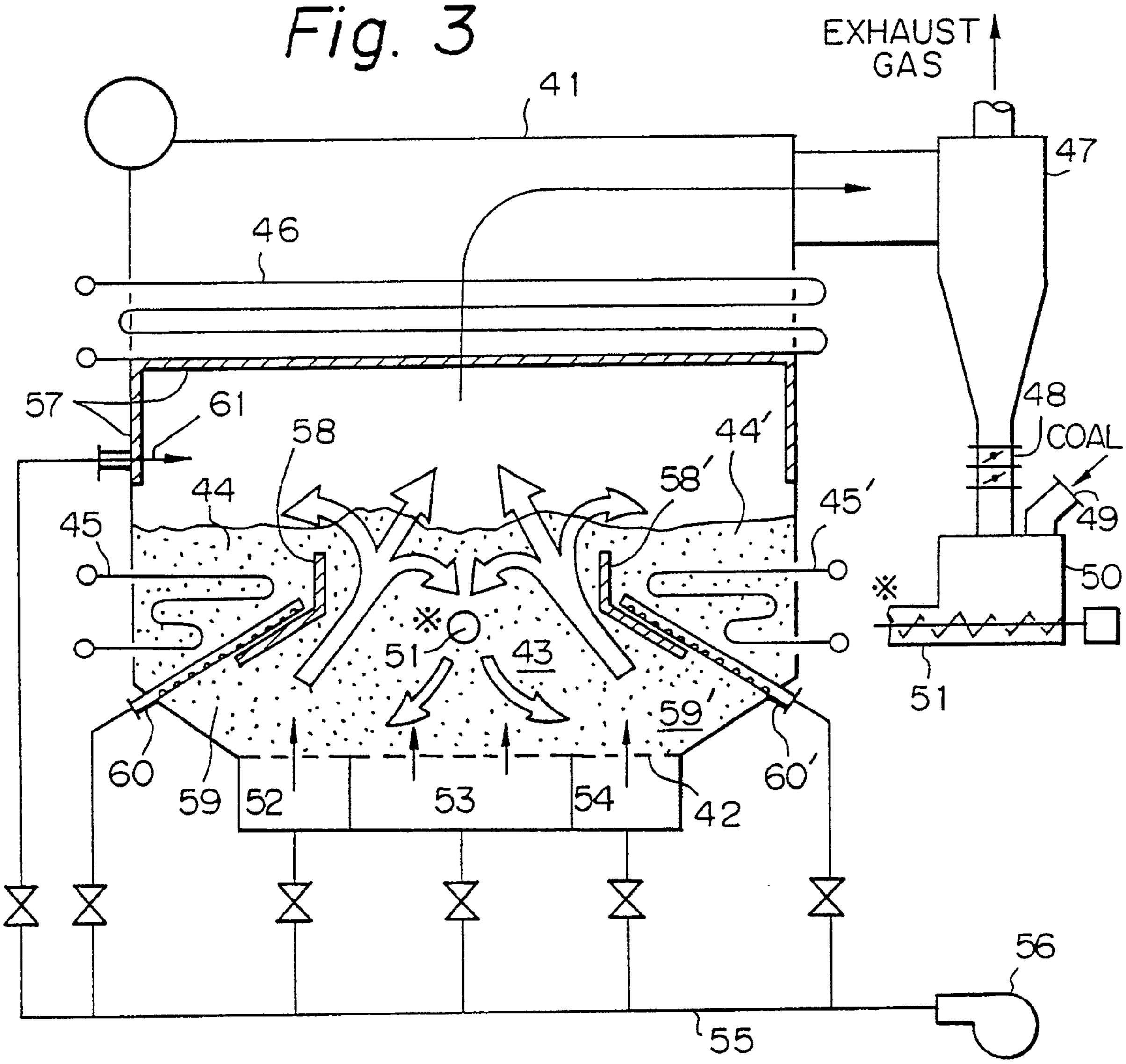
33
34
L
36
35

Fig. 3


EXHAUST GAS
41
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46
48
COAL
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61
58
44'
58'
44
45'
49
45
50
※
51
43
59'
51
60
59
52
53
54
42
60'
56
55

Fig. 4

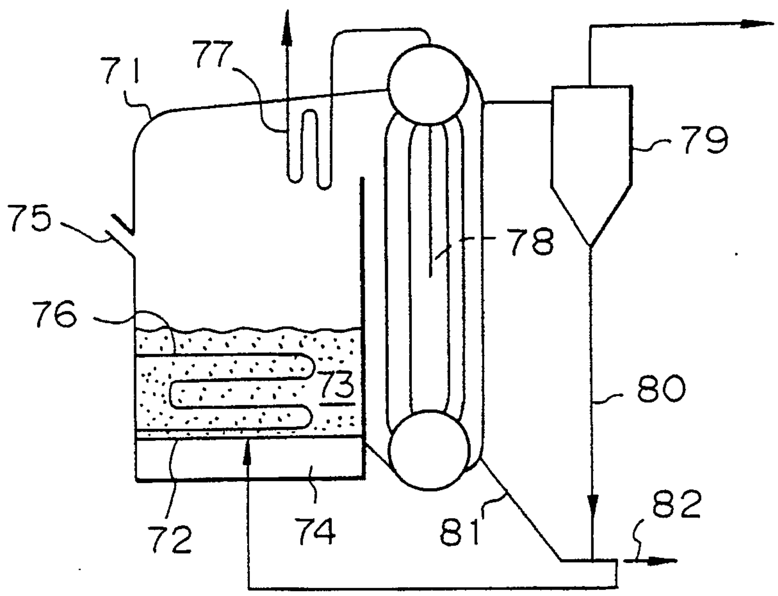
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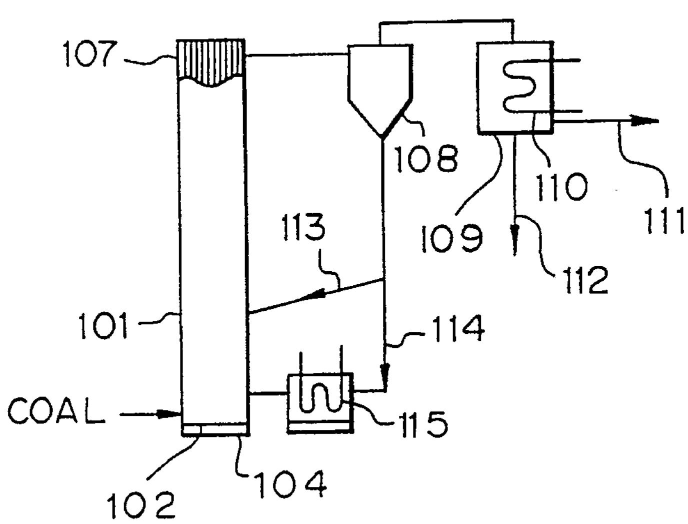
Fig. 5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112
113
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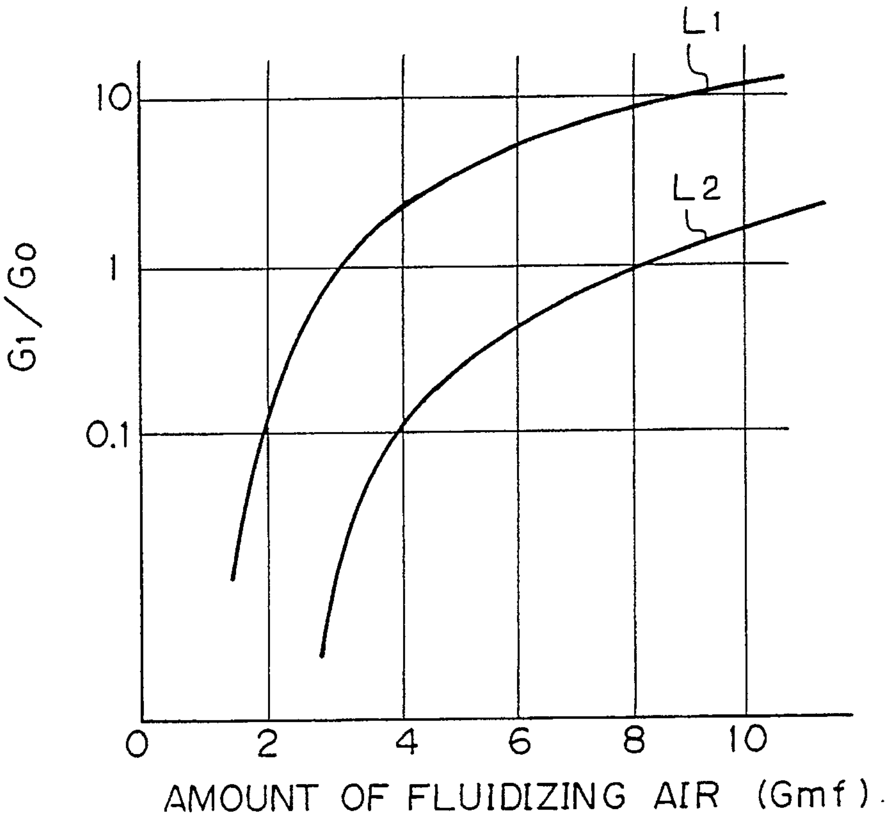
114
COAL
115
102
104

Fig. 6



Gmf MINIMUM MASS FLOW FOR FLUIDIZATION

G1 RECYCLING AMOUNT OF FLUIDIZING MEDIUM

L1 CASE WHERE TOP OF FLUIDIZED BED REACHES UPPER END OF PARTITION WITHOUT INJECTING FLUIDIZING AIR INTO BED

L2 CASE WHERE TOP OF FLUIDIZED BED IN COMBUSTING PORTION IS APPROXIMATELY AT UPPER END OF PARTITION WALL WITH INJECTING FLUIDIZING AIR INTO BED

Go RECYCLING AMOUNT OF FLUIDIZING MEDIUM IN CASE OF L1 WITH FLUIDIZING AIR MASS FLOW 3 Gmf AT LOWER END OF INCLINED PARTITION WALL IN COMBUSTION CHAMBER

Fig. 7

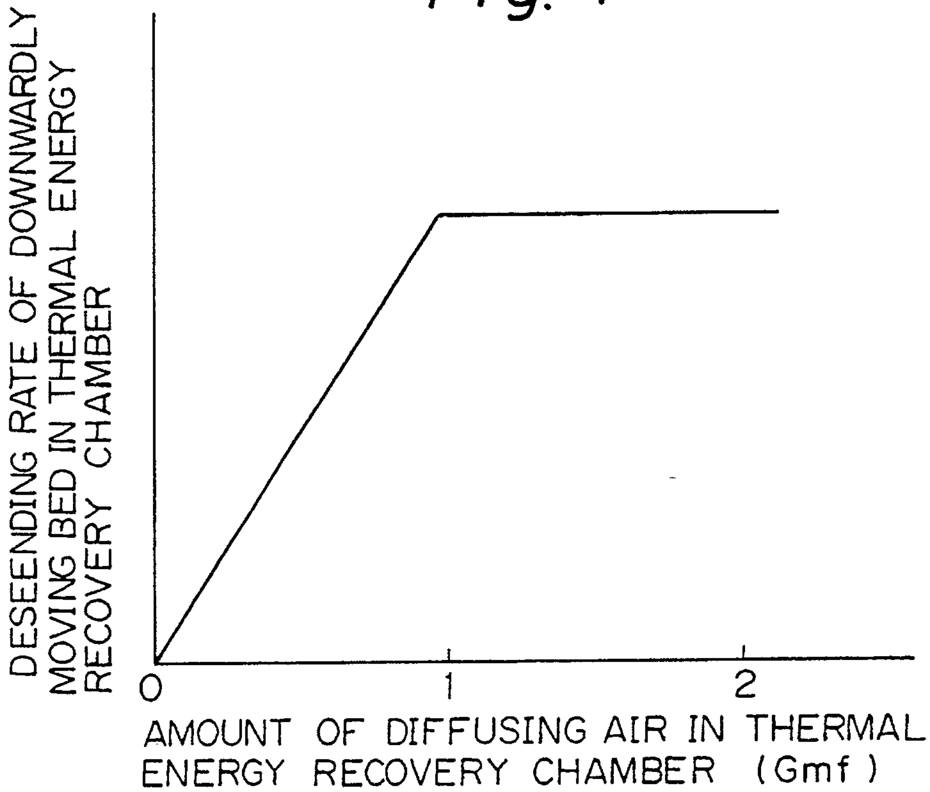

DESEENDING RATE OF DOWNWARDLY MOVING BED IN THERMAL ENERGY RECOVERY CHAMBER
0
1
2
AMOUNT OF DIFFUSING AIR IN THERMAL ENERGY RECOVERY CHAMBER (Gmf)

Fig. 8

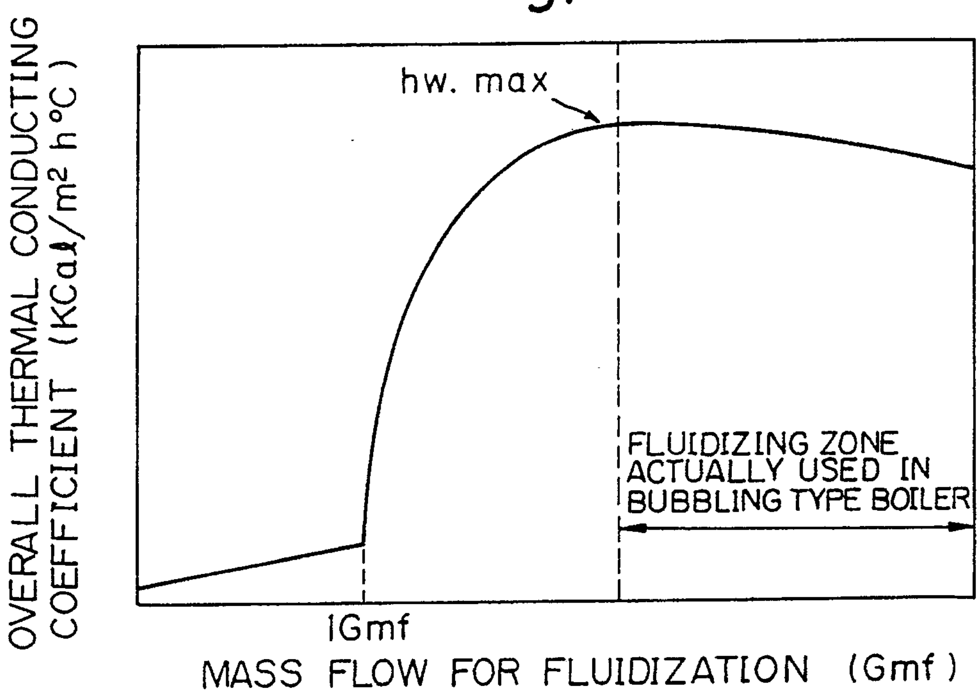

OVERALL THERMAL CONDUCTING COEFFICIENT (KCal/m² h°C)
hw. max
FLUIDIZING ZONE ACTUALLY USED IN BUBBLING TYPE BOILER
1Gmf
MASS FLOW FOR FLUIDIZATION (Gmf)

Fig. 9

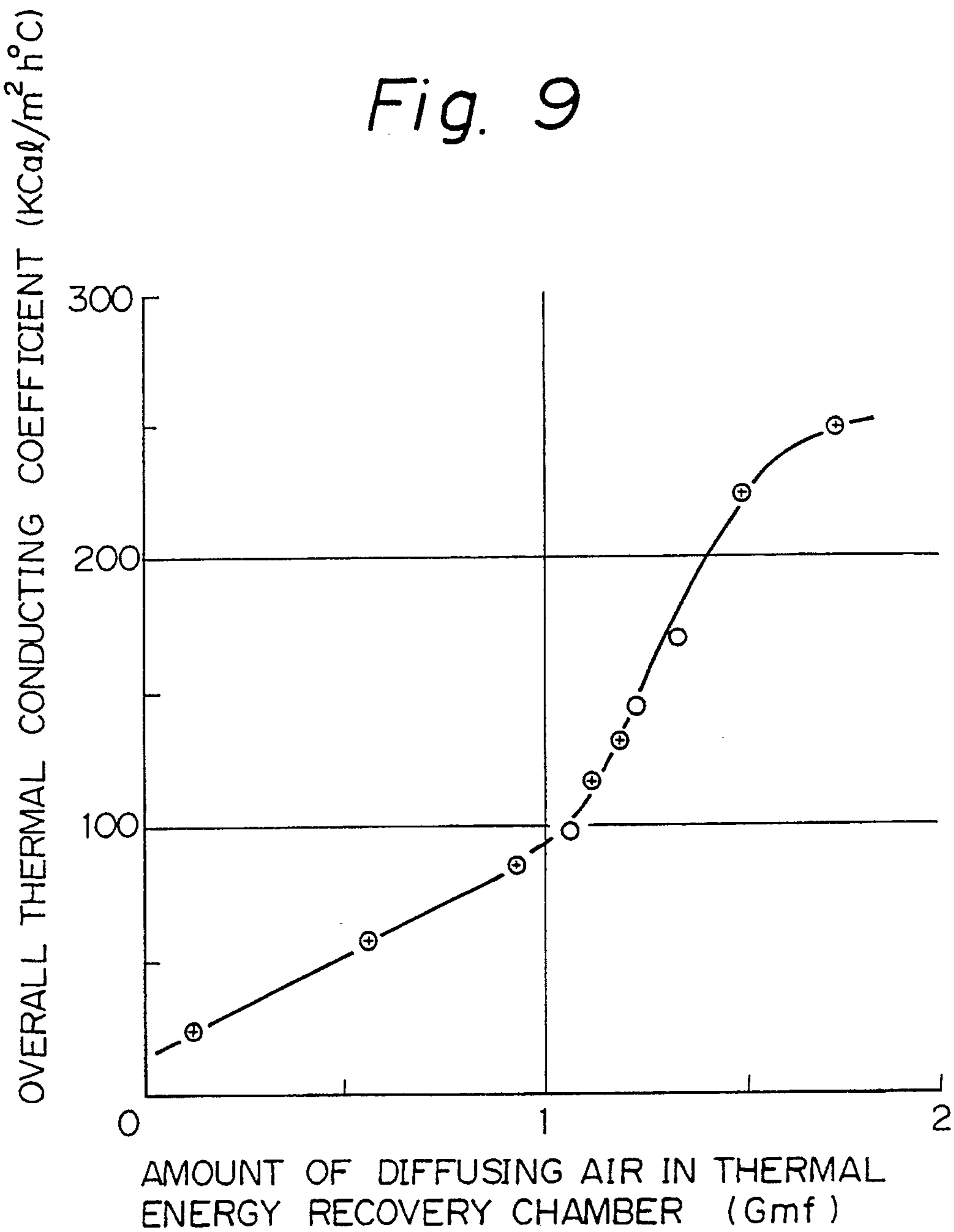

OVERALL THERMAL CONDUCTING COEFFICIENT (KCal/m²h°C)
300
200
100
0
1
2
AMOUNT OF DIFFUSING AIR IN THERMAL ENERGY RECOVERY CHAMBER (Gmf)

Fig. 10

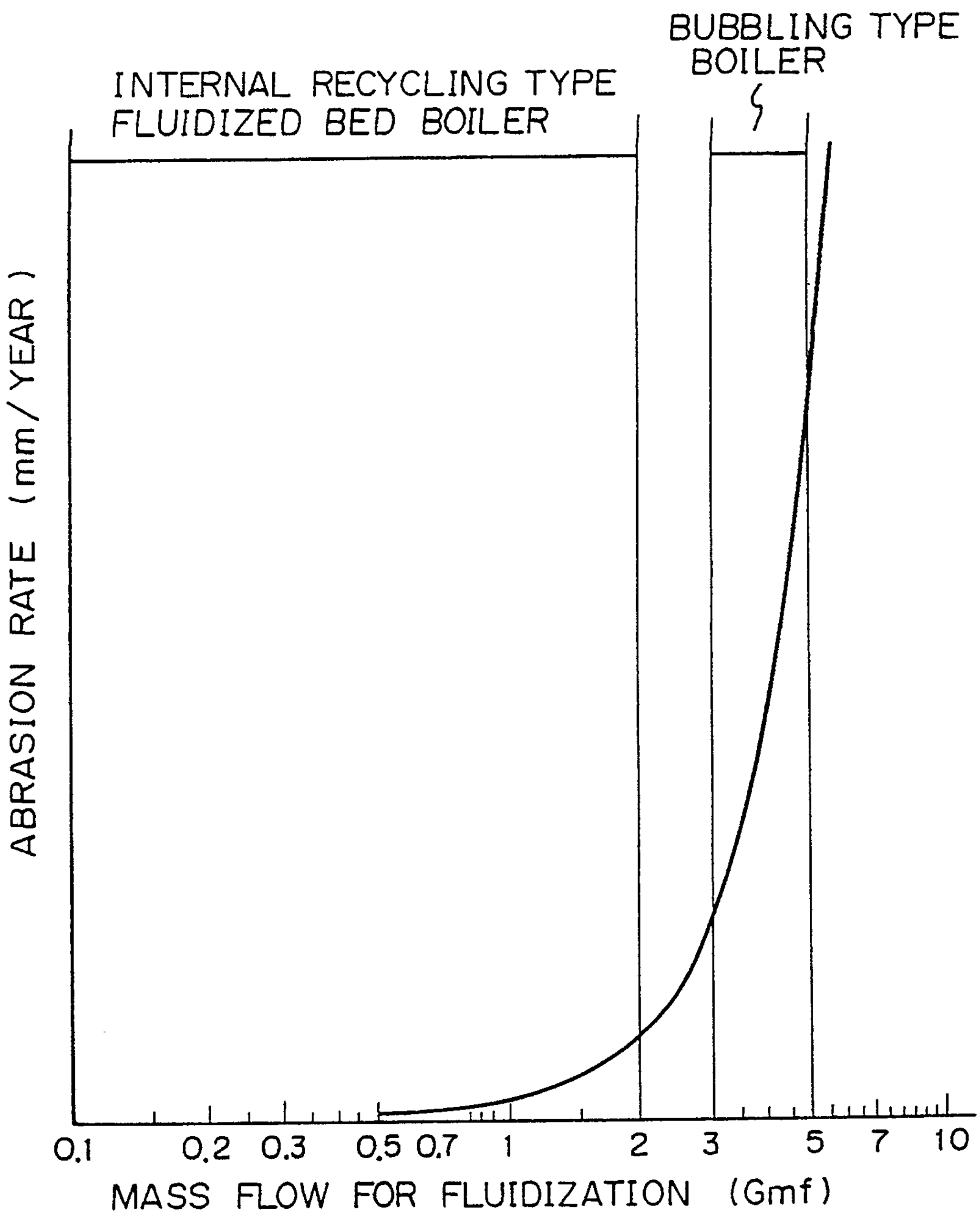

BUBBLING TYPE
BOILER
INTERNAL RECYCLING TYPE
FLUIDIZED BED BOILER
ABRASION RATE (mm/YEAR)
0.1
0.2
0.3
0.5
0.7
1
2
3
5
7
10
MASS FLOW FOR FLUIDIZATION (Gmf)

Fig. 11

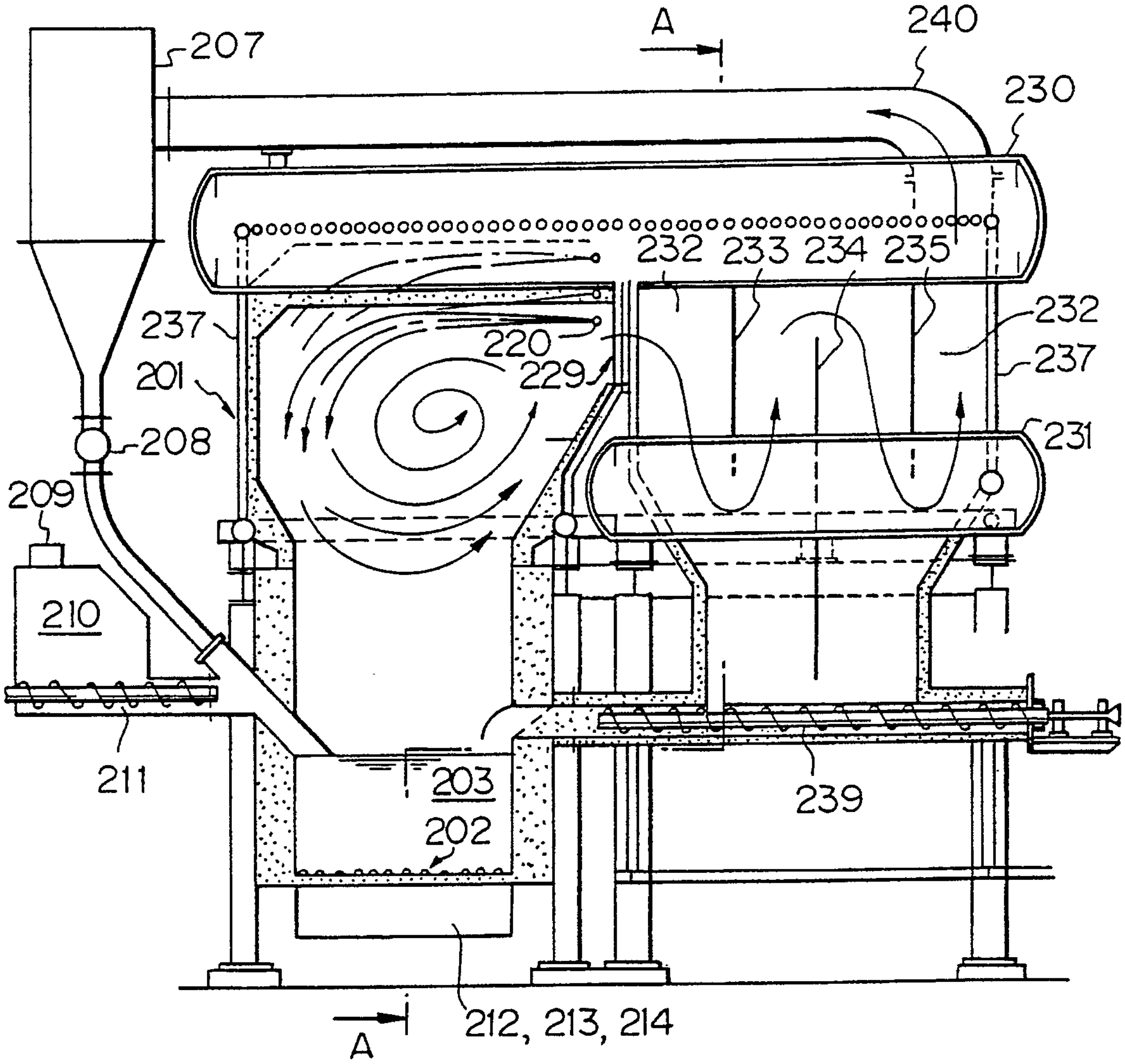

A
240
230
207
232 233 234 235
232
237
237
220
201
229
237
208
231
209
210
211
203
202
239
212, 213, 214
A

Fig. 12

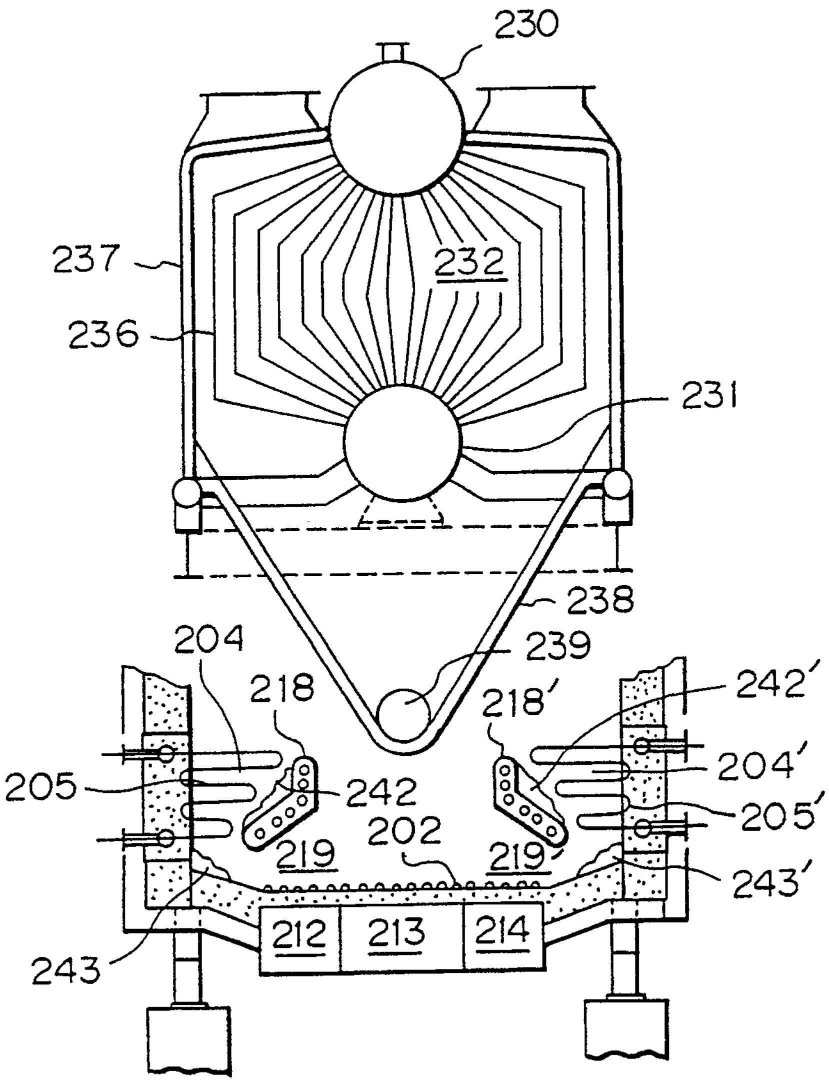
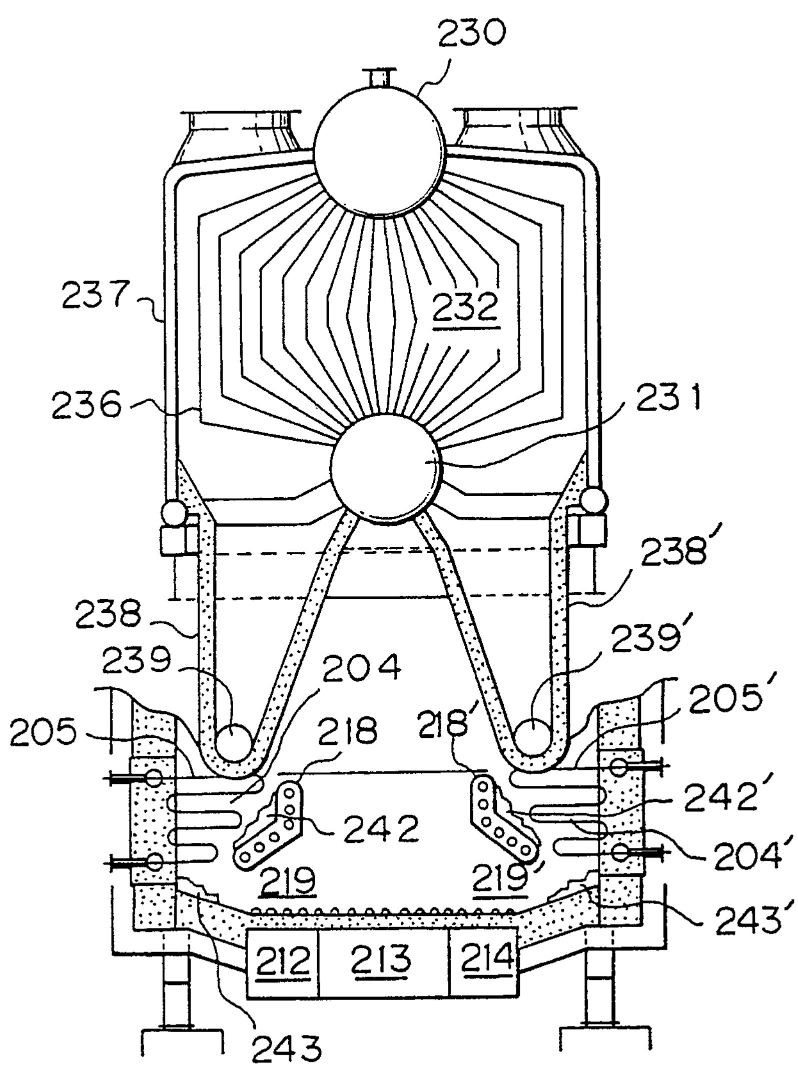

230
237
232
236
231
238
204
239
218
218'
242'
204'
205
242
205'
202
219
219'
243'
212
213
214
243

Fig. 13


230
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238'
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239'
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204
205'
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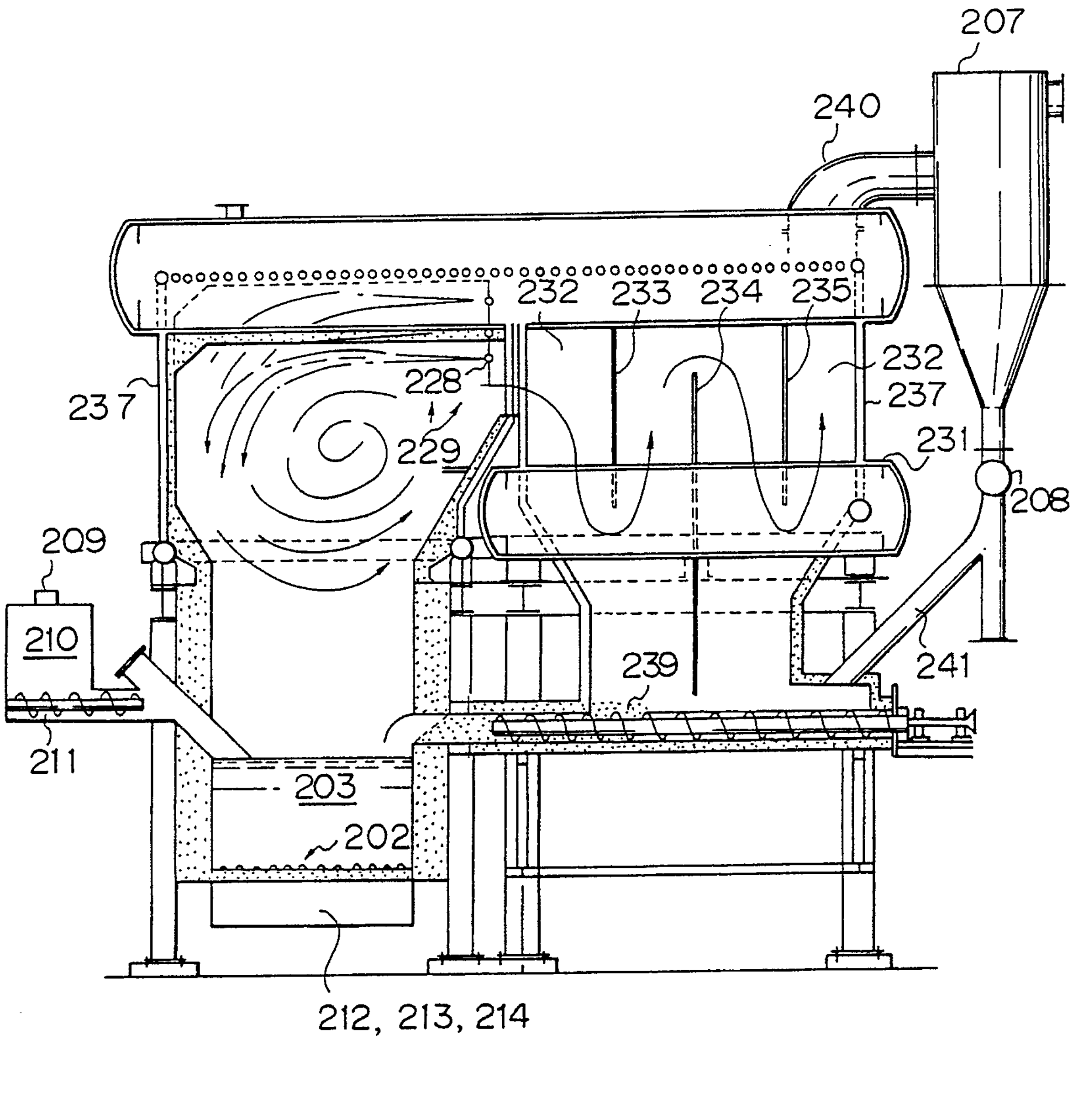
219'
243'
212
213
214
243

Fig. 14


207
240
232
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210
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241
211
203
202
212, 213, 214

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP89/00883

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl^4 F23C11/02, F22B1/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	F23C11/02, F23G5/30, F23G7/00, F22B1/02

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

Jitsuyo Shinan Koho	1926 - 1989
Kokai Jitsuyo Shinan Koho	1971 - 1989

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	JP, A, 63-73091 (Ebara Corporation) 2 April 1988 (02. 04. 88) Page 4, lower right column, line 9 to page 5, upper left column, line 17 & CN, A, 87100380 & BR, A, 8700252	1 - 6
Y	JP, A, 62-141408 (Mitsubishi Heavy Industries, Ltd.) 24 June 1987 (24. 06. 87) Page 3, lower left column, lines 9 to 13, page 3, lower right column, line 15 to page 4, upper left column, line 6 (Family : none)	1 - 6
Y	JP, A, 57-139205 (Babcock-Hitachi Kabushiki Kaisha) 28 August 1982 (28. 08. 82) Page 2, lower right column, lines 4 to 19 (Family : none)	1 - 6

* Special categories of cited documents: [10]

"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

"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

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
October 27, 1989 (27. 10. 89)	November 13, 1989 (13. 11. 89)
International Searching Authority	**Signature of Authorized Officer**
Japanese Patent Office	

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	JP, A, 63-143409 (Mitsubishi Heavy Industries, Ltd.) 15 June 1988 (15. 06. 88) (Family : none)	7 - 14

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

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

1. ☐ Claim numbers ...., because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers ...., 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. ☐ Claim numbers ...., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

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

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ 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 claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

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

☐ No protest accompanied the payment of additional search fees.