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(71) Applicant: **Babcock-Hitachi Kabushiki Kaisha**
Chiyoda-ku
Tokyo
101-0021 (JP)

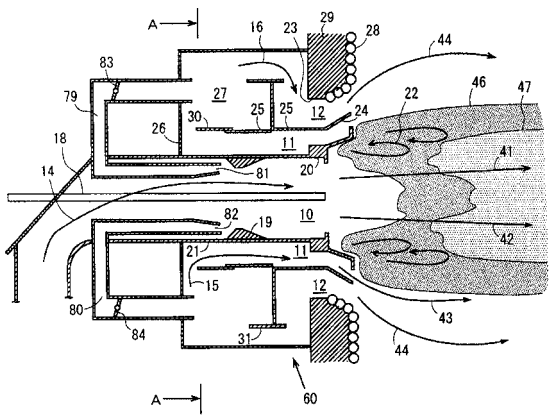
(72) Inventors:
- **OKAZAKI, Hirofumi**
  Kure-shi
  Hiroshima 737-8508 (JP)
- **KURAMASHI, Koji**
  Kure-shi
  Hiroshima 737-8508 (JP)
- **OCHI, Yusuke**
  Kure-shi
  Hiroshima 737-8508 (JP)
- **BABA, Akira**
  Kure-shi
  Hiroshima 737-8508 (JP)
- **YANO, Takanori**
  Kure-shi
  Hiroshima 737-8508 (JP)

(74) Representative: **TBK-Patent**
Bavariaring 4-6
80336 München (DE)

(54) SOLID-FUEL BURNER, COMBUSTION DEVICE USING SOLID-FUEL BURNER, AND METHOD OF OPERATING THE COMBUSTION DEVICE

(57) Provided is a solid fuel burner (60) suitable for controlling a flame to be formed by combustion of fuel ejected from the burner (60) and a temperature distribution in a furnace, a combustion apparatus using the solid fuel burner (60), and a method of operating the combustion apparatus. Providing in the fuel nozzle (10) a plurality of gas ejection nozzles (81), (82) and a restriction (obstacle) (19) downstream thereof, and ejecting a relatively large amount of gas from a portion of the gas ejection nozzles (81) provides a circumferential distribution in fuel concentration. Further, having the restriction (obstacle) (19) on a downstream side increases a deviation in fuel concentration. Providing a fuel concentration deviation in the circumferential direction makes it possible to change the forming position of a flame. Therefore, regulating the flow rate of gas flowing through the gas ejection nozzles (81), (82) makes it possible to control constant the temperature of combustion gas at a furnace exit, the temperature of a heat transfer tube provided on a furnace wall surface, the temperature of a fluid flowing through the heat transfer tube, or the temperature of a heat transfer tube provided in a furnace or at a downstream-side flue portion thereof and the temperature of a fluid flowing through the heat transfer tube.

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EP 2 221 537 A1

Description

Technical Field

[0001] The present invention relates to a solid fuel burner which is a type of pulverized coal float-firing burner, a combustion apparatus using the solid fuel burner, and a method of operating the combustion apparatus, and more particularly, to a solid fuel burner that can change a heat absorption position in a combustion apparatus by forming flame position of the solid fuel burner, a combustion apparatus using the solid fuel burner, and a method of operating the combustion apparatus.

Background Art

[0002] In a combustion apparatus, particularly, a boiler, higher steam temperature, higher steam pressure and a reheat system has been used to get higher efficiency. Normally, boiler water evaporates through water tubes that compose a furnace wall, and super-heated by a heat transfer tubes of a superheater in the furnace, and then drives a steam turbine as main steam. The steam that has driven the steam turbine is fed to a reheater to be re-heated, and then further again used for driving of the steam turbine, and become water condition through a condenser and again supplied to the furnace and used for steam generation.

[0003] It is important to obtain a prescribed amount of heat transfer to the fluid (feed water) in each heat transfer portion as heat transfer tubes to generate steam and the re-heat system. To get the prescribed amount of heat transfer, it is necessary to control the temperature and flow rate of combustion gas arises for each heat transfer portion.

[0004] Conventionally, there have been provided, as means for changing the amount of heat transfer to a fluid, two methods of changing the flow rate of combustion gas and of changing the burning position of fuel. As the former, known is a method of dividing the flow passage of combustion gas in a furnace or at a downstream-side heat transfer portion, and controlling the amount of combustion gas flow through the respective passages by a damper or the control means and the amount of heat transfer in a heat transfer tube provided in each flow passage.

[0005] As the latter, there has been provided a method of changing the ejection direction of fuel that is ejected into a furnace from a burner to change a temperature distribution in the furnace so as to control the amount of heat transfer in the furnace and at a downstream-side heat transfer portion (Patent Document 1). Further, there has been proposed a method of providing a circumferential deviation in the flow rate of combustion air flowing through a combustion air passage of a burner (Patent Document 2).

[0006] Moreover, the applicant has previously proposed a burner targeting solid fuel of low grade such as brown coal which provides additional air nozzles to inner wall portion of a fuel nozzle of the burner and which is capable of changing the amount of air to be supplied to the fuel nozzle through the additional air nozzles, and which is capable of stable combustion with a wide range from a high load condition to a low load condition, targeting solid fuel of low grade such as brown coal (Patent Document 3).

Patent Document 1: U.S. Patent Specification No. 6439136 (FIG. 2)
Patent Document 2: Japanese Published Unexamined Patent Application No. 2002-147713 (FIG. 3)
Patent Document 3: WO 02/12791

Disclosure of the Invention

Problems to be solved by the Invention

[0007] In the conventional techniques described in the above patent documents, there has been a problem the size of a control mechanism for a change in the amount of heat transfer to a fluid are big. In the case of controlling the amount of heat transfer to a fluid by the method of changing the flow rate of combustion gas, it is necessary to provide the flow passages that divide a combustion gas passage, and further, because heat transfer tubes are provided in the respective passages, the fluid channel is complicated. Moreover, it is necessary to regulate the amount of heat transfer to a fluid by controlling the amount of combustion gas flowing through each of the above-mentioned combustion gas passages by means of a damper or the like. At this time, it is necessary to take into consideration wear of the damper due to solid matter (mainly, combustion ash) in the fuel, stick with combustion ash, thermal deformation at a high-temperature portion, and the like.

[0008] The method of changing the burning position of fuel in a furnace includes two methods, one of which is to change the direction of a fuel nozzle and another of which is to change the flow rate of combustion air. In the case of the former method, it is necessary to mechanically change for the orientation of the fuel nozzle, and in this case, there is a problem of an increase in size of a drive mechanism to change the orientation of the fuel nozzle. Moreover, in the case of the former method, sufficient consideration is required for wear and ash stick when solid fuel is used, and moreover, because it becomes necessary to provide a drive mechanism in a part facing the furnace, consideration is also required for thermal deformation of the drive mechanism.

[0009] Moreover, in the case of the latter method, for the purpose of regulation of the amount of air from an air nozzle, an air amount regulation mechanism can be provided apart from the furnace, and moreover, the influence of wear and ash is also smaller than that of the former. However, because, in this case, the ejection direction of fuel changes depending on a pressure distribution in the

furnace generated by a deviation in the flow rate (momentum) of combustion air, influence of a deviation in the flow rate (momentum) of combustion air to be exerted in the ejection direction of fuel is not great, changes in the burning position within the furnace range smaller than those of the former, and the control range of the amount of heat transfer is narrower.

[0010] The invention described in Patent Document 3 is for a stable combustion of solid fuel of low grade such as brown coal even with a load change. In terms of solid fuel of low grade such as this, a gas mixture of combustion exhaust gas and air is often used as a carrier gas of fuel after pulverization. In this case, because oxygen concentration in the fuel carrier gas is lower than 21%, a combustion reaction after the fuel is ejected from the solid fuel burner may be delayed. The invention described in Patent Document 3 partially increases the oxygen concentration in the carrier gas of fuel by supplying air from the additional air nozzle, which allows a stable combustion. More specifically, the invention described in Patent Document 3 is for increasing the amount of air to be supplied from the additional air nozzle provided in the fuel nozzle at low load to raise the oxygen concentration of a circulation flow that is formed at a downstream portion outside of a fuel nozzle exit for allowing a stable combustion, while, at high load, for reducing the amount of air to be supplied from the additional air nozzle to suppress thermal radiation that a solid fuel burner structure and a furnace wall receive as a result of a flame being formed at a position distant from the fuel nozzle, and does not relate to a configuration to change the amount of heat transfer to a fluid.

[0011] The object of the present invention is to provide a method and apparatus for controlling the amount of heat transfer to the fluid by changing the burning position of fuel in a furnace by a relatively simple method.

Means for Solving the Problems

[0012] The object of the present invention is achieved by the following technical solution.

[0013] A first aspect of the invention is a solid fuel burner comprising : a fuel nozzle 10 for ejecting a fluid mixture of solid fuel and its carrier gas; and at least one air nozzle 11, 12 or 13 , arranged outside the fuel nozzle concentrically, for ejecting combustion air; which is **characterized in that** a plurality of gas ejection nozzles 81,82 that eject gas are disposed circumferentially inside the fuel nozzle 10, and a flow regulator 83 or 84that can change an ejection amount of gas from the gas ejection nozzles81,82 individually.

[0014] According to the first aspect of the invention, as a result of providing gas ejection nozzles 81,82 in a fuel nozzle 10 and ejecting gas into the fuel nozzle 10 from the gas ejection nozzles 81, 82, it becomes difficult for fuel particles to flow in on the downstream side of the gas ejection nozzles 81,82, so that the fuel concentration is reduced. Ejecting gas from a portion of the gas ejection nozzles 81,82 allows providing a fuel concentration distribution in the circumferential direction of the fuel nozzle 10. Because a fuel jet to be ejected from the solid fuel burner has a distribution in fuel concentration, the burning position of fuel in a furnace 74 can be changed.

[0015] A second aspect of the invention is the solid fuel burner according to the first aspect, wherein two or more gas ejection nozzles (81, 82) are provided vertically inside the fuel nozzle (10).

[0016] According to the second aspect of the invention, as a result of having vertically two or more gas ejection nozzles 81, 82 inside of the fuel nozzle 10 and ejecting gas from a portion of the gas ejection nozzles 81,82, a fuel concentration distribution can be provided vertically. Because a fuel jet to be ejected from the solid fuel burner thus has a fuel concentration distribution vertically, the burning position of fuel in a furnace 74 can be changed vertically.

[0017] A third aspect of the invention is the solid fuel burner according to first aspect or second aspect , wherein a restriction (19) that once contracts a passage sectional area of the fuel nozzle (10) and then enlarges the passage sectional area to an original size is provided on a downstream-side of the gas ejection nozzles (81,82).

[0018] According to the third aspect of the invention, as a result of providing a restriction on the downstream side of the gas ejection nozzles 81, 82, fuel particles flowing inside the fuel nozzle 10 are accelerated in its flow velocity at a passage contracting portion. Further, because the fuel particles have a larger mass than that of carrier gas, the velocity reduction of the fuel particles that have once been accelerated at the passage contracting portion are slower than the carrier gas, the carrier gas at a passage expanding portion. When gas is ejected by the gas ejection nozzles 81,82, a flow velocity component of the fuel particles are increased in a direction to separate from the gas ejection nozzles 81,82 on the downstream side of the gas ejection nozzles 81,82. Moreover, as a result of providing the restriction 19 on the downstream side of the gas ejection nozzles 81, 82, a flow of fuel particles is accelerated, and thus a flow deviation of the fuel particles is promoted. Therefore, as a result of providing the restriction 19, the fuel concentration deviation at the exits of the fuel nozzle 10 is increased due to the deviation in the gas flow rate from the gas ejection nozzles 81,82. Thus, the deflection in the burning position of fuel in the furnace 74 increases, and the control range of the heat transfer amount of each heat transfer portion increases.

[0019] A fourth aspect of the invention is the solid fuel burner according to the third aspect, in which the restriction 19 is provided on an outer periphery wall 21 that forms the fuel nozzle 10, or provided on a central axis portion of the fuel nozzle 10.

[0020] According to the fourth aspect of the invention, the restriction 19 can be provided to suit convenience in designing a fuel nozzle 10. For example, when a fuel that is inferior in ignitability is used, it is desirable to collect

the fuel along the outer periphery wall 21 that forms the fuel nozzle 10. When the restriction 19 is provided on the central axis portion of the fuel nozzle 10, because a flow velocity component in a peripheral direction is induced in fuel particles, it becomes possible to collect the fuel along the outer periphery wall 21 that forms the fuel nozzle 10, which promotes ignition of fuel particles to allow stably forming a flame.

[0021] A fifth aspect of the invention is the solid fuel burner according to any one of the first to fourth aspects, in which a fuel nozzle passage on a downstream-side of the gas ejection nozzle 81 or 82 provided in the fuel nozzle (10) is divided in a plurality of parts.

[0022] According to the fifth aspect of the invention, as a result of a fuel nozzle passage being divided downstream of the gas ejection nozzle 81 or 82 in a plurality of parts, a fuel concentration deviation in the fuel nozzle 10 can be kept to the exit of the fuel nozzle 10.

[0023] A sixth aspect of the invention is the solid fuel burner according to any one of the first to fifth aspects, in which at a tip portion of a peripheral outer periphery wall 21 of the fuel nozzle 10, an obstacle 20 that discharges either one or both of a flow of a fluid mixture flowing through the fuel nozzles 10 and a flow of air flowing through the air nozzle 11 is provided.

[0024] According to the sixth aspect of the invention, a region of negative pressure is formed downstream of the obstacle by a pressure of the fluid flowing around. A circulation flow 22, which is flowing in a direction reverse to the direction of an ejection from the fuel nozzle 10 or air nozzle 11 (from downstream to upstream) is formed in the part of negative pressure. A high-temperature gas generated by combustion remain in the circulation flow 22 can accelerate ignition of fuel particles flowing around. By thus forming flame ignition from the exit of the fuel nozzle 10 stably, a rapid change in the flame forming position can be avoided and it can help to keep stabilize control of the heat transfer amount of each heat transfer portions.

[0025] A seventh aspect of the invention is the solid fuel burner according to any one of first to sixth aspects, wherein a pipe expanding portion 24 that deflects an air flow in a direction to separate from the fuel nozzle 10 is provided at a tip portion of an outermost air nozzle 12 or 13 of the air nozzles 11, 12, 13.

[0026] According to the seventh aspect, because the exit of the outermost air nozzle 12 or 13 is expanded in a peripheral direction, the direction of air to be ejected from the outermost air nozzle 12 or 13 is fixed to the peripheral direction, and in particular, it becomes possible to suppress the fuel and air from mixing in the vicinity of the burner even when the flow rate is reduced.

[0027] As a method of reducing nitrogen oxides (NOx), that are generated at combustion of a solid fuel, it is well known to suppressing the mixing of the fuel and air in the vicinity of a burner and burning the fuel under air starved conditions near the burner. When the flow rate of air flowing through the outermost air nozzle 12 or 13 is reduced in a burner using this method, there is a possibility that air accompanying a fuel jet flows toward a central axis side to accelerate mixing with the fuel. However, as a result of providing a expanding portion 24 to deflect an air flow in a direction to separate from the fuel nozzle 10 at the tip portion of an outermost air nozzle 12 or 13, air to be ejected from the outermost air nozzle 12 or 13 directs to the peripheral direction as described above, and it becomes possible to suppress the fuel and air from mixing in the vicinity of the burner.

[0028] An eighth aspect of the invention is the solid fuel burner according to the seventh aspect, in which the outermost air nozzle 12 or 13 has two or more divided flow passages, and provides flow regulators 31, 32, 33 that can change an ejection amount of air individually.

[0029] According to the eighth aspect of the invention, the outermost air nozzle 12 or 13 has two or more divided flow passages circumferentially, and includes, in each passage, air flow rate regulating means 30- 33, and therefore, changing the flow rate of air flowing through the individual passages allows, for example, producing a deviation in momentum of air flows of the individual passages, which allows producing for each passage a deviation in momentum of an air jet from the outermost air nozzle 12 or 13 at the burner exit without change.

[0030] For example, when the air flow rate at the lower side of the outermost air nozzle 12 or 13 is increased, the air flow rate and flow velocity at the nozzle exit rise to increase the momentum. When fuel is horizontally ejected from the fuel nozzle 10, the fuel is guided by air from the outermost air nozzle 12 or 13, and a downward force acts. Therefore, after ejection of an air flow from the burner, the fuel is also guided by the air jet to flow deflected downward, and a flame is formed at a lower portion further than usual. Therefore, a temperature distribution in the furnace 74 deviates to the lower side of the burner, the amount of heat absorption in the furnace 74 increases, and it becomes possible to reduce the amount of heat absorption in the heat transfer tube provided in a downstream-side flue portion (a heat transfer tube of a superheater or the like suspended from a ceiling portion of the furnace or a heat transfer tube of a rear heat transfer portion) of the furnace 74.

[0031] Moreover, when the air flow rate at the upper side of the outermost air nozzle 12 or 13 is increased conversely, a flame is formed at an upper portion further than usual. Therefore, a temperature distribution in the furnace 74 deviates to the upper side, the amount of heat absorption in the furnace 74 decreases, and it becomes possible to increase the amount of heat absorption in the heat transfer tube provided in the downstream-side flue portion of the furnace 74.

[0032] A ninth aspect of the invention is a combustion apparatus comprising a controller 73 that, based on a combustion gas temperature at an exit of a furnace 74 with the solid fuel burner according to any one of first to eighth aspects arranged, a surface temperature of a heat transfer tube provided on a furnace wall surface, a sur-

face temperature of a heat transfer tube provided at a downstream-side flue portion of the furnace 74 and/or a temperature of a fluid flowing through the heat transfer tube, controls a flow rate of gas flowing through a gas ejection nozzle (81 or 82) provided in the fuel nozzle (10) of the solid fuel burner, individually in a vertical direction of the burner.

[0033] A tenth aspect of the invention is a operation method of the combustion apparatus according to ninth aspect comprising: when forming flame of solid fuel upward from the solid fuel burner, set a flow rate of gas amount relatively small for the gas ejection nozzles 81,82 setting on an upper side of the fuel nozzle 10, and set the flow rate of gas amount relatively large for the gas ejection nozzles 81,82 setting on a lower side of the fuel nozzle 10, and when forming flame of solid fuel downward from the solid fuel burner set the flow rate of gas amount relatively large for the gas ejection nozzles 81,82 setting on the upper side of the fuel nozzle 10, and set the flow rate of gas amount relatively larges for the gas ejection nozzles 82,82 setting on the lower side of the fuel nozzle 10.

[0034] According to the ninth and tenth aspects of the invention, regulating mutually the amounts of gas ejection of a plurality of gas ejection nozzles 81, 82 provided in a fuel nozzle 10 allows the fuel concentration to have a distribution in the circumferential direction of the fuel nozzle 10. For example, in the case of having gas ejection nozzles 81, 82 in a fuel nozzle 10 in the vertical direction, by ejecting gas from a gas ejection nozzle 81,82 at the upper side of the burner, fuel particles are diluted at the upper side of the fuel nozzle 10, and relatively concentrated to the lower side of the fuel nozzle 10. Therefore, after ejection of the fluid mixture from the fuel nozzle 10, the fuel burns more at the lower side of the burner, so that a high-temperature region in the furnace 74 to be produced by the combustion deviates to the lower side of the burner. Because a temperature distribution in the furnace 74 thus deviates to the lower side of the burner, the amount of heat absorption in the furnace 74 increases, which reduces the amount of heat absorption in a heat transfer tube provided in a downstream-side flue portion of the furnace 74. Moreover, by ejecting a gas from a gas ejection nozzle 81,82 at the lower side in the fuel nozzle 10, fuel particles are diluted at the lower side of the fuel nozzle 10, and relatively concentrated at the upper side of the fuel nozzle 10. Therefore, after ejection of the fluid mixture from the fuel nozzle 10 into the furnace 74, the fuel burns more at the upper side of the burner, so that a high-temperature region in the furnace to be produced by the combustion deviates to the upper side of the burner. Because a temperature distribution in the furnace 74 deviates to the upper side of the burner, the amount of heat absorption in the furnace 74 decreases, which increases the amount of heat absorption in a heat transfer tube provided in the downstream-side flue portion of the furnace 74.

[0035] Thus, providing in the flow rate of gas to be ejected from a plurality of gas ejection nozzles 81, 82 a deviation from each other for each gas ejection nozzle 81, 82 makes it possible to regulate and control the amount of heat transfer in each heat transfer portion such as a heat transfer tube provided in a furnace 74 or at a downstream-side flue portion thereof to a prescribed amount of heat transfer.

[0036] At this time, the flow rate of gas flowing through a gas ejection nozzle 81,82 contained in the fuel nozzle 10 of the solid fuel burner can be controlled individually in the vertical direction based on a combustion gas temperature at the furnace exit, a surface temperature of a heat transfer tube provided on a furnace wall surface, a surface temperature of a heat transfer tube provided at a downstream-side flue portion of the furnace 74 and/or a temperature of a fluid flowing through the heat transfer tube.

[0037] As a result, it becomes possible to change the flame forming position in order to maintain constant the temperature of a heat transfer tube installed on a wall surface of the furnace 74, the temperature of the fluid flowing through the heat transfer tube, or the temperature of a heat transfer tube provided in the furnace 74 and at a downstream-side flue portion thereof and the temperature of a fluid flowing through the heat transfer tube.

[0038] An eleventh aspect of the invention is a combustion apparatus comprising a controller 73 that, based on a combustion gas temperature at an exit of a furnace 74 with the solid fuel burner according to any one of the first to eighth aspects arranged, a surface temperature of a heat transfer tube provided on a furnace wall surface, a surface temperature of a heat transfer tube provided at a downstream-side flue portion of the furnace 74 and/or a temperature of fluid flowing through the heat transfer tube, controls a flow rate of gas flowing through a plurality of gas ejection nozzles 81, 82 provided in the fuel nozzle 10 of the solid fuel burner and a flow rate of air flowing through the outermost air nozzle 12 or 13 of the solid fuel burner, individually in a vertical direction of the burner.

[0039] A twelfth aspect of the invention is a operation method of the combustion apparatus according to the eleventh aspect, comprising: when forming flame of solid fuel upward from the solid fuel burner, set the flow rate of gas amount relatively small for the gas ejection nozzles 81,82 setting on an upper side of the fuel nozzle 10 and set the flow rate of gas amount relatively large for the gas ejection nozzles 81,82 setting on an lower side of the fuel nozzle 10, and set the flow rate of air amount relatively large for the outer side air nozzles 12,13 setting on the upper side of the fuel nozzle 10 and set the flow rate of air amount relatively small for the outer side air nozzles 12, 13 setting on the lower side of the fuel nozzle 10 and when forming flame of solid fuel downward from the solid fuel burner, set the flow rate of gas amount relatively large for the gas ejection nozzles 81,82 setting on the upper side of the fuel nozzle 10 and set the flow rate of gas amount relatively large for the gas ejection nozzles 81,82 setting on the lower side of the fuel nozzle 10, and

set the flow rate of air amount relatively small for the outer side air nozzles 12,13 setting on the upper side of the fuel nozzle 10 and set the flow rate of air amount relatively large for the outer side air nozzles 12, 13 setting on the lower side of the fuel nozzle 10.

[0040] According to the eleventh and twelfth aspects of the invention, regulation of the flow rate of gas flowing through a gas ejection nozzle 81, 82 provided in the fuel nozzle 10 and regulation of the flow rate of air flowing through the outermost air nozzle 12 or 13, allows the fuel concentration to have a distribution in the circumferential direction of the fuel nozzle 10 in a broader range than that of the ninth and tenth aspects of the invention.

[0041] For example, when the flow rate of a gas ejection nozzle at the upper side of the fuel nozzle 10 is relatively increased and the flow rate of a tertiary air nozzle 12 on the lower side of the fuel nozzle 10 is relatively increased, the amount of air is large and the amount of combustion is relatively small at the upper side of the fuel nozzle 10, and the amount of combustion is relatively large at the lower side of the fuel nozzle 10. Moreover, because, the flow rate of air from the tertiary air nozzle 12 at the lower side of the burner is large at the exit of the fuel nozzle, combustion can proceed with an appropriate ratio of fuel and air maintained. Therefore, the temperature distribution in the furnace 74 deviates to the lower side of the burner, and increase the amount of heat absorption in the furnace 74 and reduce the amount of heat absorption in the heat transfer surface (a heat transfer surface of a superheater suspended from a ceiling portion of the furnace 74 or a heat transfer surface of a superheater arranged in a rear heat transfer portion) of a heat transfer tube provided in a downstream-side flue portion of the furnace 74, and a local ratio of fuel and air can also be maintained within an appropriate range, so that a combustion condition with a combustion product such as nitrogen oxides suppressed can be maintained.

Effects of the Invention

[0042] According to the first aspect of the invention, as a result of providing gas ejection nozzles in a fuel nozzle and ejecting gas into the fuel nozzle from the gas ejection nozzles, on the downstream side of the gas ejection nozzles, it becomes difficult for fuel particles to flow in and the fuel concentration is reduced. Ejecting gas from a portion of the gas ejection nozzles allows providing a fuel concentration distribution in the circumferential direction. Because a fuel jet to be ejected from the solid fuel burner has a distribution in fuel concentration, the burning position of fuel in a furnace can be changed.

[0043] According to the second aspect of the invention, as a result of ejecting gas from a portion of two or more gas ejection nozzles provided vertically inside of the fuel nozzle, a fuel concentration distribution can be provided vertically in the furnace. Because a fuel jet to be ejected from the solid fuel burner thus has a fuel concentration distribution vertically in the furnace, the burning position of fuel in a furnace can be changed vertically.

[0044] According to the third aspect of the invention, in addition to the effects of the first or second aspect of the invention, fuel particles flowing inside the fuel nozzle are accelerated in its flow velocity at a passage contracting portion due to a restriction provided on the downstream side of the gas ejection nozzle, and a flow deviation of the fuel particles is promoted. Therefore, the fuel concentration deviation at the fuel nozzle exit due to the deviation in the flow rate of gas to be ejected from the gas ejection nozzles is increased. Thus, the deflection in the burning position of fuel in the furnace increases, and the control range of the heat transfer amount of each heat transfer portion increases.

[0045] According to the fourth aspect of the invention, in addition to the effects of the third aspect of the invention, for example, when a fuel that is inferior in ignitability is used, it is desirable to collect the fuel along the outer periphery wall that forms the fuel nozzle. When the restriction is provided on the central axis portion of the fuel nozzle, because a flow velocity component in a peripheral direction is induced in fuel particles flowing inside the fuel nozzle, it becomes possible to collect the fuel along the outer periphery wall that forms the fuel nozzle, which promotes ignition of fuel particles to allow stably forming a flame.

[0046] According to the fifth aspect of the invention, in addition to the effects of any one of the first to fourth aspects, as a result of a fuel nozzle passage being divided downstream of the gas ejection nozzle in a plurality of parts, a fuel concentration deviation in the fuel nozzle can be maintained up to the exit of the fuel nozzle.

[0047] According to the sixth aspect of the invention, in addition to the effects of any one of the first to fifth aspects, because a circulation flow is formed in a downstream portion of the obstacle, flame ignition can be formed stably from the fuel nozzle exit, and a rapid change in the flame forming position in the furnace can be avoided and control of the heat transfer amount of each heat transfer portion can be stable.

[0048] According to the seventh aspect, in addition to the effects of any one of the first to sixth aspects, as a result of providing a expanding portion to deflect an air flow in a direction to separate from the fuel nozzle at the tip portion of the outermost air nozzle, air to be ejected into the furnace from the outermost air nozzle directs to the peripheral side, and it becomes possible to suppress the fuel and air from mixing in the vicinity of the burner in the furnace.

[0049] According to the eighth aspect of the invention, in addition to the effects of any one of the first to seventh aspects, a distribution of air to be ejected from the outermost air nozzle into the furnace can be provided, and the amount of heat absorption in the furnace and a downstream-side flue portion of the furnace can be regulated.

[0050] According to the ninth and tenth aspects of the invention, regulating mutually the amounts of gas ejection of a plurality of gas ejection nozzles provided in a

fuel nozzle allows the fuel concentration to have a distribution in the circumferential direction of the fuel nozzle. Thus, providing in the flow rate of gas to be ejected from a plurality of gas ejection nozzles a deviation from each other for each gas ejection nozzle makes it possible to regulate and control the heat transfer amount in each heat transfer portion, such as in a heat transfer tube provided in a furnace or at a downstream-side flue portion thereof, to a prescribed amount of heat transfer.

[0051] According to the eleventh and twelfth aspects of the invention, by regulation of the flow rate of gas flow through a plurality of gas ejection nozzles contained in the fuel nozzle and regulation of the flow rate of air flowing through the outermost air nozzle, control in the flame forming position at the exit of the solid fuel burner can be performed in a broader range than that of the ninth and tenth aspects of the invention, and moreover, a local ratio of fuel and air can also be maintained within an appropriate range, so that a combustion condition can be maintained and the combustion product such as nitrogen oxides can be suppressed.

Best Mode for Carrying Out the Invention

[0052] Embodiments of the present invention will be described below together with the drawings.

[Embodiment 1]

[0053] A sectional schematic view of a solid fuel burner showing Embodiment 1 of the present invention is shown in FIG. 1, and shown in FIG. 2 is a schematic view of a flame forming state in a furnace when the flow rate of gas to be ejected from a gas ejection nozzle in the section of the solid fuel burner of FIG. 1 is changed. Moreover, a sectional view taken along an arrow line A-A of FIG. 1 is shown in FIG. 3. FIG. 4 shows a schematic view when the solid fuel burner shown in Embodiment 1 is incorporated in a furnace. Further, FIG. 5 and FIG. 6 show modifications of Embodiment 1 of the present invention.

[0054] In FIG. 1, a fuel nozzle 10 that is connected to a fuel pipe (not shown) of a fluid mixture 14 of solid fuel (pulverized coal) and its carrier gas on an upstream side and that supplies the fluid mixture 14 is provided, and eject secondary air 15 is provided on the periphery of the fuel nozzle 10 concentrically. Moreover, a tertiary air nozzle 12 that ejects tertiary air 16 is provided on the periphery of the secondary air nozzle 11 concentrically with the secondary air nozzle 11, and the tertiary air nozzle 12 serves as an outermost air nozzle in this case.

[0055] An oil gun 18 is provided penetrating through a center portion of the fuel nozzle 10, and the oil gun 18 ejects oil for assisting combustion from its tip at start-up or low-load combustion of the burner 60. Moreover, a restriction (obstacle) 19 is provided on an inner wall of the fuel nozzle 10, which also has a role of preventing a backfire of solid fuel.

[0056] An obstacle called a flame stabilizing ring 20 is provided at the tip portion (furnace exit side) of a outer periphery wall 21 that separates the fuel nozzle 10 and the secondary air nozzle 11 from each other.

[0057] A burner throat portion 23 opening in a furnace wall 29 serves also as an outer peripheral wall of the tertiary air nozzle 12. Moreover, an expanding portion 24 is provided at a tip portion of a outer periphery wall 25 that separates the secondary air nozzle 11 and the tertiary air nozzle 12 from each other is a pipe expanding portion 24, which is a guiding member (guide sleeve). Moreover, combustion air is introduced from a wind box 27, and supplied into the furnace separated as the secondary air 15 and the tertiary air 16. A damper 30 is provided in the wind box 27, that regulates the flow rate of the secondary air 15 flowing in the secondary air nozzle 11 and a damper 31 is provided that regulates the flow rate of the tertiary air 16 flowing in the tertiary air nozzle 12. Moreover, ducts 79, 80 are provided on a outer periphery wall 26 of the wind box 27, and the ducts 79, 80 are connected with gas ejection nozzles 81, 82 within the fuel nozzle 10, respectively. A plurality of gas ejection nozzles 81, 82 are provided in the circumferential direction of an inner wall side of the fuel nozzle 10, and the gas ejection nozzles 81, 82 introduce, from the wind box 27 by way of the ducts 79, 80, combustion air as a gas flowing through the gas ejection nozzles 81, 82 in the present embodiment.

[0058] The gas ejection nozzles 81, 82 are installed on an upstream side of the restriction (obstacle) 19. Moreover, regulating dampers 83, 84 are provided in the ducts 79, 80, respectively, and the regulating dampers 83, 84 regulate the flow rate of gas to be ejected from the gas ejection nozzles 81, 82. A plurality of gas ejection nozzles 81, 82 are provided in the circumferential direction of the fuel nozzle 10.

[0059] Further, a water tube 28 for steam generation is provided on the furnace wall 29.

[0060] Moreover, due to a flow 41, 42 of the fluid mixture (fuel jet) 14 of pulverized coal and its carrier gas (primary air) ejected into a furnace 74 from the fuel nozzle 10, a flow 43 of the secondary air 15 ejected from the secondary air nozzle 11, and a flow 44 of the tertiary air 16 ejected from the tertiary air nozzle 12, a flame 46 and a high-temperature region 47 in the flame 46 are produced.

[0061] Next, FIG. 4 is a schematic view of a combustion apparatus for which the solid fuel burner 60 of the present invention is provided on a sidewall 75 of the furnace 74.

[0062] Solid fuel is supplied from a fuel hopper 68 to a pulverizer 66 and finely pulverized. The finely pulverized solid fuel is fed to the fuel nozzle 10 of the solid fuel burner 60 by carrier air from a carrier air fan 67 by way of a fuel carrying tube 65. Combustion air is supplied to the solid fuel burner 60 from an air fan 70 by way of an air duct 61 with a flow regulating valve (not shown).

[0063] In generally, the furnace 74 provide the plural number of the above-mentioned solid fuel burner 60, but the description of the present embodiment shows the

case of a single solid fuel burner 60 is connected to the furnace 74, for an example.

[0064] The sidewall 75 that forms the furnace 74 is composed of water tubes, and absorbs combustion heat. Further heat transfer surface 76 of composed with heat transfer tubes are arranged at a downstream-side of the furnace 74 as a superheater. Moreover, for measuring the amount of heat absorption in the water tubes of the sidewall 75 and the heat transfer surface 76 of the furnace 74, thermometers that measures the temperature of water and steam or the temperature of a material that forms the water tube and the heat transfer tube are installed at an appropriate position.

[0065] Provided in FIG. 4 is a control processor 73 that controls the regulating dampers 83, 84 (FIG. 1, FIG. 2) of the gas ejection nozzle of the solid fuel burner 60 based on a steam temperature at the exit of water tube of the furnace 74 and a steam temperature the an exit of the heat transfer surface 76.

[0066] A combustion state in the present embodiment will be first described based on FIG. 1. In the case of combustion in the solid fuel burner 60, gas in a downstream-side region of the outer periphery wall 21, that separates the fuel nozzle 10 and the secondary air nozzle 11 from each other, is guided by gas ejected into the furnace 74 from each of the nozzles 10, 11. The flame stabilizing ring 20 provided at the tip portion of the outer periphery wall 21 acts as an obstacle to the flow (hereinafter sometimes referred to as a pulverized coal jet) 41, 42 of the fluidmixture 14 of fuel and its carrier gas ejected from the fuel nozzle 10 and the flow 43 of the secondary air 15 through the secondary air nozzle 11. Therefore, the pressure on a downstream side (inside of the furnace) of the flame stabilizing ring 20 decreases, whereby a flow is induced in the direction reverse to the pulverized coal jet 41, 42 and the flow 43 of the secondary air 12 in this part. This flow in the reverse direction is called a circulation flow 22. A high-temperature gas generated by combustion of the pulverized coal flows into the circulation flow 22 from downstream of the burner 60 in the furnace 74, and resides there. Forming this high-temperature gas near the pulverized coal jet 41, 42 accelerates ignition and allow stably flame.

[0067] As a result of a flame being formed in the furnace 74 near an exit of the fuel nozzle 10, it promotes oxygen consumption and spread a reducing flame region of low oxygen concentration in the flame. Nitrogen content contained in the solid fuel (pulverized coal) is released in this reducing flame as a reducing substance such as ammonia and cyan, and acts as a reducing agent that changes nitrogen oxides (NOx) to nitrogen. Therefore, the production of NOx can be reduced. Moreover, a combustion reaction of the solid fuel proceeds as a result of the acceleration of ignition, and an unburnt carbon content in fuel ash (hereinafter, referred to as unburnt carbon) is also reduced. As a result of providing the expanding portion 24 at an exit of the tertiary air nozzle 12 guide the tertiary air 16 toward the periphery of the burner 60, and let the flow 41, 42 of the fluid fuel mixture and the flow 44 of the tertiary air 16 flow separately, so that mixing of the fuel and tertiary air in the furnace 74 near the burner 60 is delayed, and the reducing flame region can spread.

[0068] Next, features of the present embodiment will be described by use of FIG. 1 and FIG. 2.

[0069] FIG. 1 schematically shows a distribution of a combustion gas in the furnace 74 when equal amounts of gas (combustion air) are flown from the gas ejection nozzles 81, 82, while FIG. 2 schematically shows a distribution of a combustion gas in the furnace 74 when a larger amount of gas is introduced from the gas ejection nozzle 81 installed at an upper side of the fuel nozzle 10 than that from the gas ejection nozzle 82 installed at a lower side of the fuel nozzle 10.

[0070] When the gas flow rate from the gas ejection nozzle 81 is increased as in FIG. 2, on the downstream side of the gas ejection nozzle 81 it becomes difficult for fuel particles to flow in and the fuel concentration is reduced. Thus ejecting a larger amount of gas from a portion 81 of the gas ejection nozzles as such allows the fuel concentration to have a distribution in the circumferential direction of the fuel nozzle 10.

[0071] For example, in the case shown in FIG. 2, by having the gas ejection nozzles 81, 82 in the vertical direction of the fuel nozzle 10 and ejecting a larger amount of gas from the gas ejection nozzle 81 at the upper side of the fuel nozzle 10 than that from the gas ejection nozzle 82 at the lower side of the fuel nozzle 10, fuel particles are diluted at the upper side, and relatively concentrated to the lower side. Therefore, after ejection of the fluid fuel mixture 14 from the fuel nozzle 10, the fuel burns more at the lower side of the burner 60 in the furnace 74, so that a high-temperature region in the furnace 74 produced by the combustion deviates to the lower side. Because a temperature distribution in the furnace 74 deviates to the lower side of the burner 60, the amount of heat absorption in the furnace 74 increases at the lower side of the burner 60, which reduces the amount of heat absorption in a heat transfer tube provided in a downstream portion (the heat transfer surface 76 suspended from a ceiling portion of the furnace 74 such as a super heater or the like, and the heat transfer surface 76 composed with heat transfer tubes at a rear heat transfer portion shown in FIG. 4) of the furnace 74.

[0072] In the present embodiment, the gas ejection nozzles 81, 82 are provided on the upstream side of the restriction (obstacle) 19, while fuel particles flowing through the fuel nozzle 10 are accelerated in its flow velocity at a passage contracting portion in the combustion nozzle 10 by creation of the restriction (obstacle) 19. Further, because the fuel particles when that have once been accelerated have a larger mass than that of the carrier gas, the flow velocity is slowly reduced compared with the carrier gas also at a passage expanding portion in the combustion nozzle 10 due to the restriction (obstacle) 19. Therefore, by providing a deviation in fuel concentra-

tion by the gas ejection nozzles 81, 82 on the upstream side of the passage contracting portion, a flow deviation of the fuel particles is promoted in the passage contracting portion. Therefore, the fuel concentration deviation at the exit of the fuel nozzle 10 due to the deviation in the gas flow rate from the gas ejection nozzles 81, 82 is increased. For example, the flow 41, 42 of fuel particles in the fuel nozzle 10 flows deflected to the lower side of the burner 60 as shown in FIG. 2. Therefore, the deflection at the burner 60 exit of the high-temperature part 47 in the furnace 74 is large, and the control range of the heat transfer amount of each heat transfer portion increases.

[0073] Moreover, by providing the restriction (obstacle) 19 in the fuel nozzle 10, a passage sectional area of the fuel nozzle 10 is narrowed, and thus the flow velocity of the fluid fuel mixture 14 is high, and a backfire due to a backflow of fuel particles into the fuel nozzle 10 can be prevented. In particular, when an oxygen containing gas such as air is ejected from the gas ejection nozzles 81, 82, spontaneous combustion near the gas ejection nozzles 81, 82 can be prevented by providing the restriction 19.

[0074] The restriction (obstacle) 19 may be installed at a peripheral portion of the combustion-assisting oil gun 18 provided in a center portion of the fuel nozzle 10 as shown in FIG. 6.

[0075] Alternatively, as shown in FIG. 5, in the case of a configuration with no restriction (obstacle) 19 provided in the fuel nozzle 10, where the passage sectional area of the fuel nozzle 10 is constant, the fuel deviation is smaller than that when the restriction (obstacle) 19 exists, however, when gas is ejected from the gas ejection nozzles 81, 82, it becomes difficult for fuel particles to flow in on the downstream side thereof, so that an effect of a reduction in fuel concentration is obtained. For example, in the case shown in FIG. 5, by having the gas ejection nozzles 81, 82 in the vertical direction of the fuel nozzle 10 and ejecting a larger amount of gas from the gas ejection nozzle 81 at the upper side of the fuel nozzle 10 than that from the gas ejection nozzle 82 at the lower side of the fuel nozzle 10, fuel particles are diluted at the upper side of the fuel nozzle 10, and relatively concentrated to the lower side of the fuel nozzle 10, the flow 41, 42 of fuel particles in the fuel nozzle 10 flows deflected to the lower side of the burner 60 as shown in FIG. 2, the deflection at the burner 60 exit of the high-temperature part 47 in the furnace 74 is large, and the control range of the heat transfer amount of each heat transfer portion increases.

[0076] Also, it is desirable for the gas ejection nozzles 81, 82 to secure small flow rate for preventing deposition of fuel particles.

[0077] Next, a state of combustion or heat transfer in the furnace will be described by use of FIG. 4.

[0078] A deviation given to the flow rate of air flowing through the gas ejection nozzles 81, 82 provided in the fuel nozzle 10 makes it possible to control the forming position of the flame 46, 47 in the furnace 74 to the vertical direction of the burner 60 exit in the furnace 74. At this time, it is difficult to directly measure the forming position of the flame 46, 47 in the furnace 74 filled with a high-temperature gas. Therefore, it is desirable to individually control the flow rate of air flowing through the gas ejection nozzles 81, 82 of the solid fuel burner 60, based on the combustion gas temperature at the exit of the furnace 74, the temperature of a heat transfer tube installed on a wall surface of the furnace 74, the temperature of a fluid flowing through the heat transfer tube, or the temperature of a heat transfer tube provided in the furnace 74 and at a downstream-side flue portion thereof and the temperature of a fluid flowing through the heat transfer tube.

[0079] For example, the combustion gas temperature at the exit of the furnace 74 and the temperature of a heat transfer tube provided on a furnace wall surface and a fluid flowing therethrough are indicators of the amount of heat absorption within the furnace 74. When the amount of heat absorption within the furnace 74 is large, the combustion gas temperature lowers, and the heat transfer tube temperature and the fluid temperature in the furnace 74 rise. Moreover, it indicates when the temperature of a heat transfer tube having the heat transfer surface 76 provided at the downstream-side flue portion of the furnace 74 and the temperature of a fluid flowing through the heat transfer tube are low that the amount of heat absorption in the furnace 74 is relatively large.

[0080] When the amount of heat absorption within the furnace 74 is lowered relative to that of the heat transfer surface 76 of a furnace rear portion, it is desirable to form the flame 46, 47 upward. In this case, increasing the amount of air from, of the gas ejection nozzles 81, 82, the lower gas ejection nozzle 82 that collect fuel particles in the fuel nozzle 10 to the upper side of the fuel nozzle 10, allows forming the flame 46 upward.

[0081] Moreover, when the amount of heat absorption within the furnace 74 is raised relative to that of the heat transfer surface 76 of a furnace rear portion, it is desirable to form a flame downward as in the flame 46, 47 shown in FIG. 2. In this case, increasing the amount of air from the gas ejection nozzle 81 at the upper side of the fuel nozzle 10 that collect fuel particles in the fuel nozzle 10 to the lower side, allows forming a flame downward as in the flame 46, 47 (FIG. 2).

[0082] Moreover, for the solid fuel burner 60 of the present embodiment, provided at the tip of the outer periphery wall 21 on the peripheral side of the fuel nozzle 10 is a flame stabilizing ring 20 that prevents a flow of the fluid mixture 14 flowing through the fuel nozzle 10 and air flowing through the air nozzle 11. Moreover, a expanding portion 24 that deflects a flow to the peripheral side (direction to separate from the fuel nozzle) is provided at the exit of the outermost air nozzle 12.

[0083] The flame stabilizing ring 20 as an obstacle to a flow of fuel and air ejected from each nozzle 10, 11, on the outer periphery wall 21 between the fuel nozzle 10

and the air nozzle 11 forms a circulation flow 22 in the furnace 74. As a result of a high-temperature gas existing in this circulation flow 22 and igniting the fuel, it becomes possible to fix an ignition position of a flame near the circulation flow 22 at the exit of the fuel nozzle 10. By thus fixing an ignition position allows, even when a deviation is provided in the fuel concentration, fixing a flame formation start position. Therefore, it becomes easier to control the temperature distribution in the furnace 74 and the amount of heat absorption in the furnace 74, and the amount of heat absorption in the heat transfer tube having the heat transfer surface 76 provided at a downstream portion of the furnace 74.

[0084] Also, a burning position of fuel in the furnace 74 is controlled in the present embodiment by the flow rate of air that is ejected from the gas ejection nozzles 81, 82 contained in the fuel nozzle 10. The method of changing the burning position of fuel in the furnace 74 includes two other methods of changing the orientation of the fuel nozzle 10 and of changing the flow rate of combustion air. In the case of the present embodiment, a deviation is provided in the concentration of fuel to be ejected from the solid fuel burner 60, and the same effect of changing the orientation of the fuel nozzle 10 can be obtained. Further, the flow regulating dampers 83, 84 that are used for regulation of the fuel concentration can be provided at a position apart from a position facing the inside of the furnace 74. Therefore, thermal deformation of the movable portions are less, so that reliability is improved. Moreover, because a deviation is provided in fuel particles (concentration) by the flow rate of gas, there is no contact with the particles. Therefore, the reliability of operation of the movable portion is increased from the point of view of the fixation of the particles and wear.

[Embodiment 2]

[0085] FIG. 7 is a schematic view showing a section of a solid fuel burner 60 showing a second embodiment of the present invention. A configuration of Embodiment 2 different from that of Embodiment 1 shown in FIG. 1 and FIG. 2 is that, in FIG. 7, a partition 90 that divides the fuel nozzle 10 vertically is provided on the downstream side of the gas ejection nozzles 81, 82 and the restriction (obstacle) 19 provided in the fuel nozzle 10, and other aspects of the configuration are the same as those of Embodiment 1, and thus description of those will be omitted.

[0086] Although a description in the present embodiment shows the partition 90 as the division wall of the fuel nozzle 10 vertically in halves, but it is possible to treat the partition 90 as a circular cylindrical member arranged concentrically with the fuel nozzle 10.

[0087] Dividing the flow passage in the fuel nozzle 10 by the partition 90 allows maintaining a fuel concentration deviation in the fuel nozzle 10 up to the exit of the fuel nozzle 10. In the case of the second embodiment shown in FIG. 7, by having the gas ejection nozzles 81, 82 in the vertical direction of the fuel nozzle 10 and ejecting gas from the gas ejection nozzle 81 at the upper side of the fuel nozzle 10, fuel particles at the exit of the fuel nozzle 10 are diluted at the upper side of the fuel nozzle 10, and relatively concentrated to the lower side of the fuel nozzle 10. Further, by installing the gas ejection nozzles 81, 82 on the upstream side of the restriction (obstacle) 19, a flow deviation of the fuel particles is promoted. Therefore, a deviation in fuel concentration at the exit of the fuel nozzle 10 due to a deviation in the flow rate of gas from the gas ejection nozzles 81, 82 is increased. By dividing the fuel nozzle 10 on the downstream side of the restriction (obstacle) 19, a fuel deviation at the exit of the fuel nozzle 10 is maintained. Here, a flow regulation of the gas ejection nozzles 81, 82 and effects thereof are as described in Embodiment 1 of the present invention.

[Embodiment 3]

[0088] FIG. 8 and FIG. 9 are schematic views showing sections of a solid fuel burner 60 showing a third embodiment of the present invention. Moreover, FIG. 10 is a schematic view of the solid fuel burner 60 shown in FIG. 8, observed from a furnace 74 side. Further, FIG. 11 is a schematic view showing a modification of the third embodiment, observed from a furnace 74 side.

[0089] A configuration of the present embodiment different from that of Embodiment 1 shown in FIG. 1 is that, in FIG. 8, tertiary air nozzles 12, 13 are divided as separate air nozzles that form passages in the vertical direction.

[0090] Moreover, a pair of partitions 90, 90 that divide the fuel nozzle 10 vertically are provided on the downstream side of the restriction (obstacle) 19. Although a description in the present embodiment in FIG. 10 shows a pair of partitions 90, 90 that divide the fuel nozzle 10 in the vertical direction, but it is possible to treat a single partition 90 as the division wall of the fuel nozzle 10 concentrically.

[0091] Moreover, although flow regulating dampers 31, 32 are provided in the tertiary air nozzles 12, 13 in the present embodiment, respectively, it is possible to set a configuration that regulates the air flow rate without using a wind box to supply combustion air to the tertiary air nozzles 12, 13 individually.

[0092] In FIG. 9, shown is a case where the flow rate of air flowing through the tertiary air nozzle 12 on the upper side of the fuel nozzle 10 is reduced, and the flow rate of air flowing through the tertiary air nozzle 13 on the lower side of the fuel nozzle 10 is increased.

[0093] Due to a difference in the flow rate of air flowing through the upper and lower tertiary air nozzles 12, 13, a tertiary air jet ejected into the furnace 74 from the solid fuel burner 60 deflects in the vertical direction. Concretely, the flow rate of air flowing through the tertiary air nozzle 13 on the lower side of the fuel nozzle 10 is increased further than the flow rate of air flowing through the tertiary air nozzle 12 on the upper side of the fuel nozzle 10, and

a flow velocity of ejection there from into the furnace 74 is also increased. In terms of momentum that is determined by a product of the flow rate and the ejection velocity, not only does an axial momentum of the burner 60 grow, but a downward momentum also increases.

[0094] Due to a tertiary air jet, a negative pressure is generated because ambient gas is caught in the jet at the exit of the nozzles 12, 13, and secondary air flowing near the tertiary air jet flows deflected downward due to the negative pressure. Further, because the circulation flow 22 also deflects to the lower side according to the secondary air flow 43, a fuel jet flowing near the circulation flow 22 also deflects downward.

[0095] The point of providing, at the exit of the fuel nozzle 10, a fuel deviation in the vertical direction by dividing the gas ejection nozzles 81, 82 provided in the fuel nozzle 10 in the vertical direction and providing a deviation in the flow rate of air flowing through the individual passages, is as shown in Embodiment 1. Further, because providing a deviation in the flow rate of tertiary air makes it possible to control the forming position of a flame within the furnace 74 in the vertical direction in the present embodiment, the control range increases due to a synergetic effect.

[0096] For example, when the flow rate of the gas ejection nozzle 81 at the upper side of the fuel nozzle 10 is relatively increased, at the exit of the fuel nozzle 10, the fuel jet 41, 42 is relatively small in the fuel amount at the upper side of the burner 60, and relatively large at the lower side of the burner 60. Therefore, the fuel jet 41, 42 that is ejected from the fuel nozzle 10 into the furnace 74 is ejected in a horizontal direction, but is different in the vertical direction of the fuel concentration in the furnace 74 near the burner 60 exit, and fuel flows deflected toward the lower fuel jet 42 of the burner 60.

[0097] Further, when the flow rate of the lower tertiary air nozzle 13 of the fuel nozzle 10 is relatively increased, due to a pressure distribution at the nozzle exit because of the momentum deviation of the air jet mentioned above, the fuel jet 42 flowing by the air jet flows deflected to the lower side of the burner 60. More specifically, because the fuel that is ejected into the furnace 74 from the fuel nozzle 10 is supplied deflected to the lower side of the burner 60, the forming position of a flame also deviates to the lower side.

[0098] Moreover, because the fuel concentration is supplied deflected to the lower side of the fuel nozzle 10 and the tertiary air also flows more to the lower side of the fuel nozzle 10, combustion can proceed with an appropriate ratio of fuel and air maintained. Therefore, the temperature distribution in the furnace 74 deviates to the lower side to increase the amount of heat absorption in the furnace 74 and reduce the amount of heat absorption in the heat transfer surface 76 (a heat transfer surface of a superheater suspended from a ceiling portion of the furnace or a heat transfer surface of a superheater arranged in a rear heat transfer portion) of a heat transfer tube provided in a downstream-side flue portion of the furnace 74, and a local ratio of fuel and air can also be maintained within an appropriate range, so that a combustion condition with a combustion product such as nitrogen oxides suppressed can be maintained.

[0099] FIG. 11 is a modification of Embodiment 3, showing a schematic view of a solid fuel burner 60, observed from a furnace 74 side. The burner 60 shown in FIG. 11 is an example, different in the structure of a tertiary air nozzle from the burner 60 of Embodiment 3 shown in FIG. 10, where the tertiary air nozzle is circumferentially divided in quarters to form nozzles 12, 13, 91, 92.

[Embodiment 4]

[0100] FIG. 12 is a schematic view of a combustion apparatus for which a solid fuel burner 60 of the present invention is provided on a sidewall 75 of a furnace 74.

[0101] The solid fuel burner 60 includes a fuel nozzle 10, air nozzles 12, 13 shown in FIG. 1 etc., although not shown in FIG. 12 and gas ejection nozzles 81, 82 contained in the fuel nozzle 10. Solid fuel supplied from a fuel hopper 68 to a solid fuel pulverizer 66 is pulverized, and fed to the fuel nozzle 10 by carrier air from a carrier air fan 67 by way of a fuel carrying tube 65.

[0102] Combustion air is supplied to the air nozzles 12, 13 from an air fan 70 by way of an air duct 61 with a flow regulating valve 69. Moreover, supplied to the gas ejection nozzles 81, 82 is air from the air fan 70 by way of air ducts 62, 63 branching off from the air duct 61 and including flow regulating valves 71, 72, respectively.

[0103] In generally, the furnace 74 provides the plural number of the above-mentioned solid fuel burner 60, but the description of the present embodiment shows the case of a single solid fuel burner 60 is connected to the furnace 74, for an example.

[0104] The sidewall 75 that forms the furnace 74 is composed of water tubes, and absorbs combustion heat. Further arranged at a downstream side of the furnace 74 is a heat transfer surface 76 of a heat transfer tube such as a superheater or the like within the furnace 74. Moreover, for measuring the amount of heat absorption in the water tubes of the sidewall 75 of the furnace 74 and the heat transfer surface 76, a thermometer that measures the temperature of water and steam or the temperature of a material that forms the water tube and the heat transfer tube is installed at an appropriate position.

[0105] Provided in FIG. 12 is a control processor 73 that controls the flow regulating valves 71, 72 based on a steam temperature at a water tube exit of the furnace 74 and a steam temperature at an exit of the heat transfer surface 76.

[0106] Moreover, in the combustion apparatus shown in FIG. 12, combustion air is ejected into the fuel nozzle 10 from the gas ejection nozzles 81, 82 provided vertically in the fuel nozzle 10, respectively.

[0107] By ejecting gas into the fuel nozzle 10 from the gas ejection nozzle 81 at the upper side of the fuel nozzle

10, fuel particles are diluted at the upper side of the fuel nozzle 10, and relatively concentrated to the lower side of the fuel nozzle 10. Therefore, after ejection into the furnace 74 from the fuel nozzle 10, the fuel burns more on the lower side of the burner 60, so that a high-temperature region in the furnace to be produced by the combustion deviates to the lower side of the burner 60. Because a temperature distribution in the furnace 74 deviates to the lower side of the burner 60, the amount of heat absorption in the furnace 74 increases, which makes it possible to reduce the amount of heat absorption in the heat transfer surface 76 provided in the heat transfer surface 76 (a heat transfer surface of a superheater or the like suspended from a ceiling portion of the furnace or a heat transfer surface of a superheater arranged in a rear heat transfer portion) of a heat transfer tube provided in a downstream portion of the furnace 74. Moreover, when a larger amount of gas is ejected from the gas ejection nozzle 82 at the lower side of the burner 60 conversely, a flame is formed within the furnace 74 at an upper side of the burner 60 further than usual, a temperature distribution in the furnace 74 deviates to the upper side of the burner 60, the amount of heat absorption in the furnace 74 decreases, which allows increasing the amount of heat absorption in the heat transfer surface 76 of the heat transfer tube provided in a downstream portion of the furnace 74.

[0108] For example, FIG. 13 shows a calculation result of a gas temperature at the furnace 74 exit when the solid fuel burner of the present embodiment is applied to a pulverized coal-fired boiler. With the same amount of heat input to the fuel 74, the gas temperature at the furnace 74 exit lowers when the amount of heat absorption within the furnace 74 is large, and the gas temperature rises when the amount of heat absorption in the furnace 74 is small. Thus, the gas temperature at the furnace exit closely relates to control of the proportion of heat absorption of the furnace 74 and the heat transfer surface 76 of a heat transfer tube installed downstream thereof. Particularly, when the gas temperature at the furnace exit is high, the material temperature of the heat transfer surface 76 of a heat transfer tube installed downstream thereof increases, and therefore the heat transfer surface 76 is protected using the gas temperature as an indicator in some cases.

[0109] It is indicated that changing the ratio of the flow rates of gas to be ejected from the gas ejection nozzles 81, 82 allows changing the gas temperature, that is, the amount of heat absorption within the furnace 74.

Industrial Applicability

[0110] The present invention is a solid fuel burner that allows easily changing the position of heat absorption within a combustion apparatus, and has high applicability to a furnace, such as a boiler, that is excellent in combustion efficiency.

Brief Description of the Drawings

[0111]

FIG. 1 is a sectional schematic view of a solid fuel burner of Embodiment 1 of the present invention.

FIG. 2 is a sectional schematic view of a solid fuel burner, for explaining an operation state of Embodiment 1.

FIG. 3 is a sectional view taken along an arrow line A-A of FIG. 1.

FIG. 4 is a schematic view of a combustion apparatus for which the solid fuel burner of Embodiment 1 of the present invention is provided on a furnace wall.

FIG. 5 shows a modification of the solid fuel burner of Embodiment 1 of the present invention.

FIG. 6 shows a modification of the solid fuel burner of Embodiment 1 of the present invention.

FIG. 7 is a sectional schematic view of a solid fuel burner of Embodiment 2 of the present invention.

FIG. 8 is a sectional schematic view of a solid fuel burner of Embodiment 3 of the present invention.

FIG. 9 is a sectional schematic view of a solid fuel burner, for explaining an operation state of Embodiment 3.

FIG. 10 is a schematic view of the solid fuel burner of FIG. 8, observed from a furnace side.

FIG. 11 is a schematic view of a solid fuel burner of a modification of Embodiment 3 of the present invention, observed from a furnace side.

FIG. 12 is a schematic view of a combustion apparatus of Embodiment 4 of the present invention.

FIG. 13 is an example of a graph showing furnace exit temperature changes, for explaining an operation state of the combustion apparatus of Embodiment 4 of the present invention.

Description of Reference Numerals

[0112]

10 Fuel nozzle 11 Secondary air nozzle

12, 13 Outermost (tertiary) air nozzle

14 Fluid mixture 15 Secondary air

16 Tertiary air 18 Oil gun

19 Restriction (obstacle) 20 Obstacle (flame stabilizing ring)

21, 25, 26 Outer periphery wall 22 Circulation flow

23 Burner throat 24 Expanding portion (guide member)

27 Wind box 28 Water tube

29 Furnace wall 30, 31, 32 Flow regulating damper

41, 42 Fuel jet flow 43 Secondary air flow

44 Tertiary air flow 46 Flame

47 High-temperature region of flame 60 Burner

61, 62, 63 Air duct 74 Furnace

66 Pulverizer 65 Fuel pipe

67 Carrier air fan 68 Fuel hopper

69, 71, 72 Flow regulating valve 70 Air fan

73 Control processor 75 Sidewall

76 Heat transfer surface 79, 80 Duct

81, 82 Gas ejection nozzle 83, 84 Regulating damper

90 Partition 91, 92 Outermost (tertiary) air nozzle

Claims

1. A solid fuel burner comprising:

a fuel nozzle (10) for ejecting a fluid mixture of solid fuel and its carrier gas; and
at least one air nozzle(11, 12 or 13), arranged outside the fuel nozzle concentrically, for ejecting combustion air;
which is **characterized in that** a plurality of gas ejection nozzles (81, 82) that eject gas are disposed circumferentially inside the fuel nozzle (10), and a flow regulator (83 or 84) that can change an ejection amount of gas from the gas ejection nozzle (81 or 82) individually.

2. The solid fuel burner according to claim 1, wherein two or more gas ejection nozzles (81,82) are provided vertically inside the fuel nozzle (10).

3. The solid fuel burner according to claim 1 or 2, wherein a restriction (19) that once contracts a passage sectional area of the fuel nozzle (10) and then enlarges the passage sectional area to an original size is provided on a downstream-side of the gas ejection nozzles (81,82).

4. The solid fuel burner according to claim 3, wherein the restriction (19) is provided on an outer periphery wall (21) that forms the fuel nozzle(10), or provided on a central axis portion of the fuel nozzle(10).

5. The solid fuel burner according to any one of claims 1 to 4, wherein a fuel nozzle passage on a downstream-side of the gas ejection nozzle (81 or 82) provided in the fuel nozzle (10) is divided in a plurality of parts.

6. The solid fuel burner according to any one of claims 1 to 5, wherein at a tip portion of a peripheral outer periphery wall (21) of the fuel nozzle (10), an obstacle (20) that discharges either one or both of a flow of a fluid mixture flowing through the fuel nozzle (10) and a flow of air flowing through the air nozzle (11) is provided.

7. The solid fuel burner according to any one of claims 1 to 6, wherein a pipe expanding portion (24) that deflects an air flow in a direction to separate from the fuel nozzle (10) is provided at a tip portion of an outermost air nozzle (12 or 13) of the air nozzles (11,12,13).

8. The solid fuel burner according to claim 7, wherein the outermost air nozzle (12 or 13) has two or more divided flow passages, and provides flow regulators (31, 32, 33) that can change an ejection amount of air individually.

9. A combustion apparatus comprising a controller (73) that, based on a combustion gas temperature at an exit of a furnace (74) with the solid fuel burner according to any one of claims 1 to 8 arranged, a surface temperature of a heat transfer tube provided on a furnace wall surface, a surface temperature of a heat transfer tube provided at a downstream-side flue portion of the furnace (74) and/or a temperature of a fluid flowing through the heat transfer tube, controls a flow rate of gas flowing through a gas ejection nozzle (81 or 82) provided in the fuel nozzle (10) of the solid fuel burner, individually in a vertical direction of the burner.

10. A operation method of the combustion apparatus according to claim 9 comprising:

when forming flame of solid fuel upward from the solid fuel burner, set a flow rate of gas amount relatively small for the gas ejection nozzles (81,82) setting on an upper side of the fuel nozzle (10), and set the flow rate of gas amount relatively large for the gas ejection nozzles (81, 82) setting on a lower side of the fuel nozzle (10),and
when forming flame of solid fuel downward from the solid fuel burner set the flow rate of gas amount relatively large for the gas ejection nozzles (81, 82) setting on the upper side of the fuel nozzle (10), and set the flow rate of gas amount relatively larges for the gas ejection nozzles (82, 82) setting on the lower side of the fuel nozzle

(10).

11. A combustion apparatus comprising; a controller (73) that, based on a combustion gas temperature at an exit of a furnace (74) with the solid fuel burner according to any one of claims 1 to 8 arranged, a surface temperature of a heat transfer tube provided on a furnace wall surface, a surface temperature of a heat transfer tube provided at a downstream-side flue portion of the furnace (74) and/or a temperature of fluid flowing through the heat transfer tube, controls a flow rate of gas flowing through a plurality of gas ejection nozzles (81,82) provided in the fuel nozzle (10) of the solid fuel burner and a flow rate of air flowing through the outermost air nozzle (12 or 13) of the solid fuel burner, individually in a vertical direction of the burner.

12. A operation method of the combustion apparatus according to claim 11, comprising:

when forming flame of solid fuel upward from the solid fuel burner, set the flow rate of gas amount relatively small for the gas ejection nozzles (81,82) setting on an upper side of the fuel nozzle (10) and set the flow rate of gas amount relatively large for the gas ejection nozzles (81, 82) setting on an lower side of the fuel nozzle (10), and set the flow rate of air amount relatively large for the outer side air nozzles (12, 13)setting on the upper side of the fuel nozzle (10) and set the flow rate of air amount relatively small for the outer side air nozzles (12, 13) setting on the lower side of the fuel nozzle(10)
and when forming flame of solid fuel downward from the solid fuel burner, set the flow rate of gas amount relatively large for the gas ejection nozzles (81, 82) setting on the upper side of the fuel nozzle (10) and set the flow rate of gas amount relatively large for the gas ejection nozzles (81, 82) setting on the lower side of the fuel nozzle (10), and set the flow rate of air amount relatively small for the outer side air nozzles (12, 13) setting on the upper side of the fuel nozzle (10) and set the flow rate of air amount relatively large for the outer side air nozzles (12, 13) setting on the lower side of the fuel nozzle (10).

FIG. 1

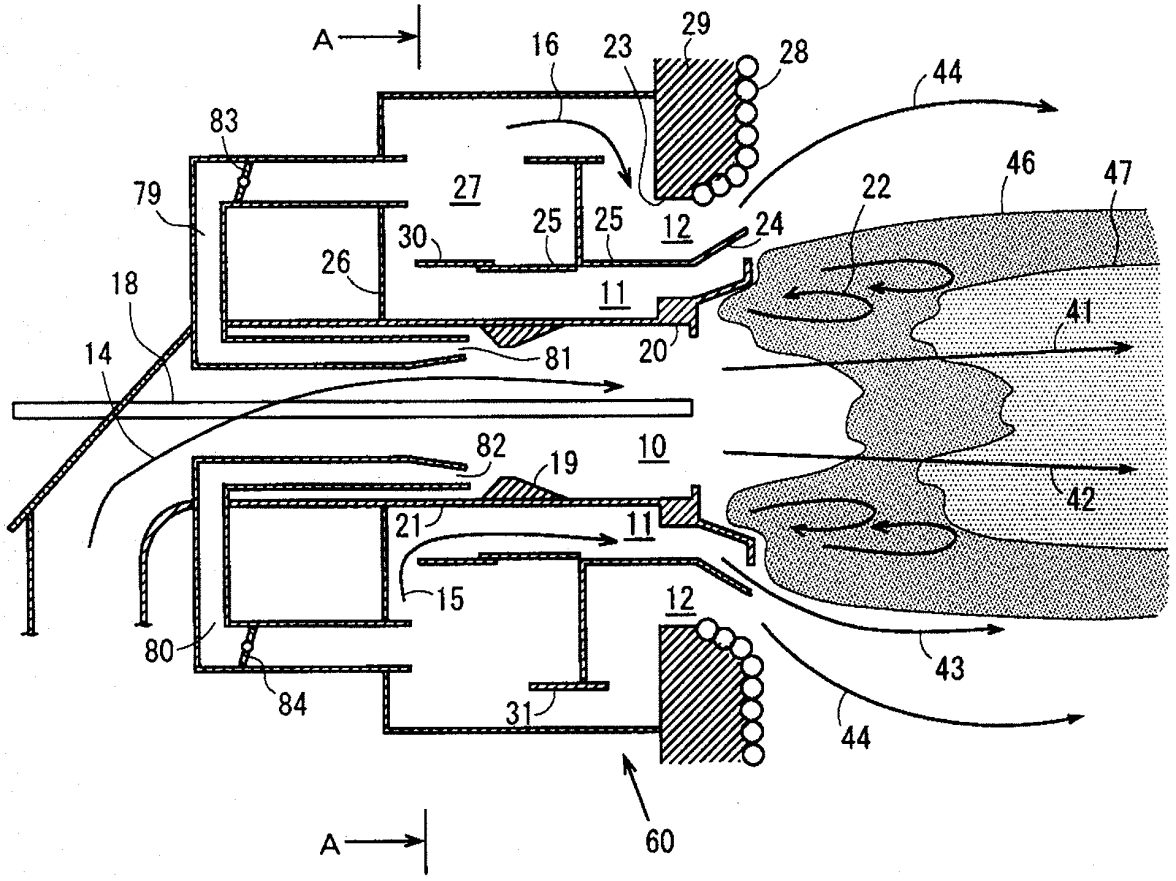

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FIG. 2

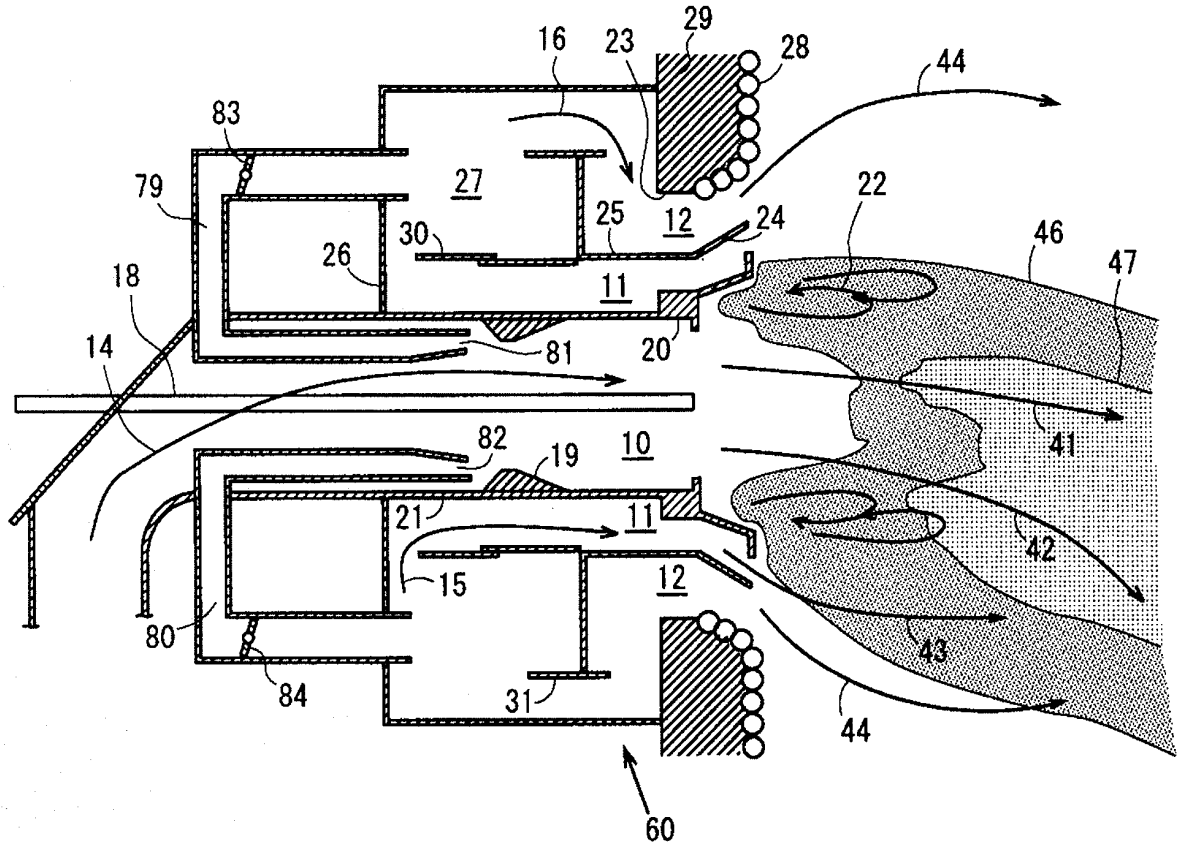

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FIG. 3

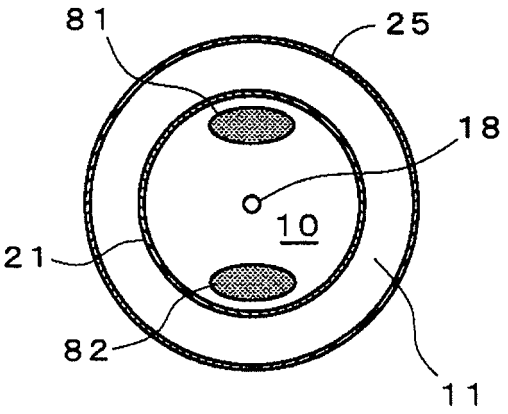


FIG. 4

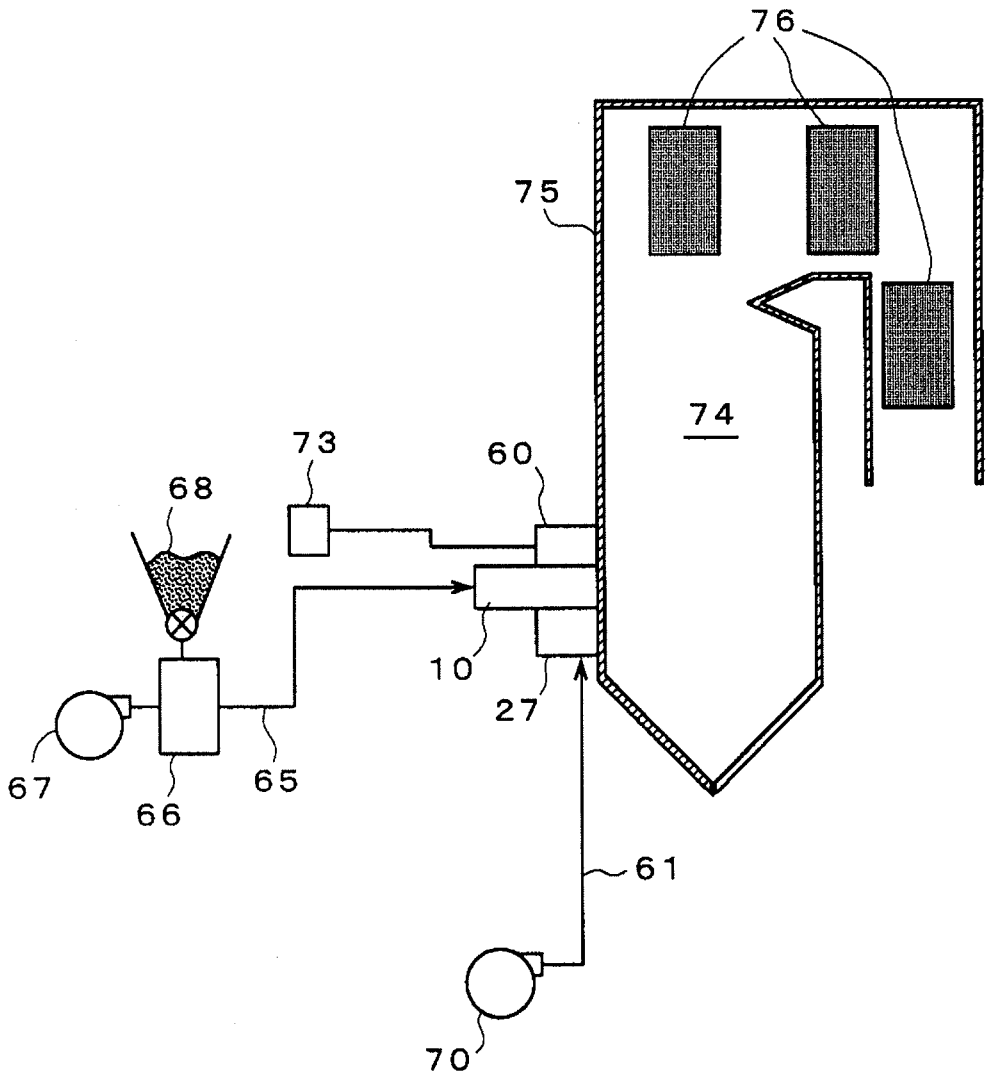


FIG. 5

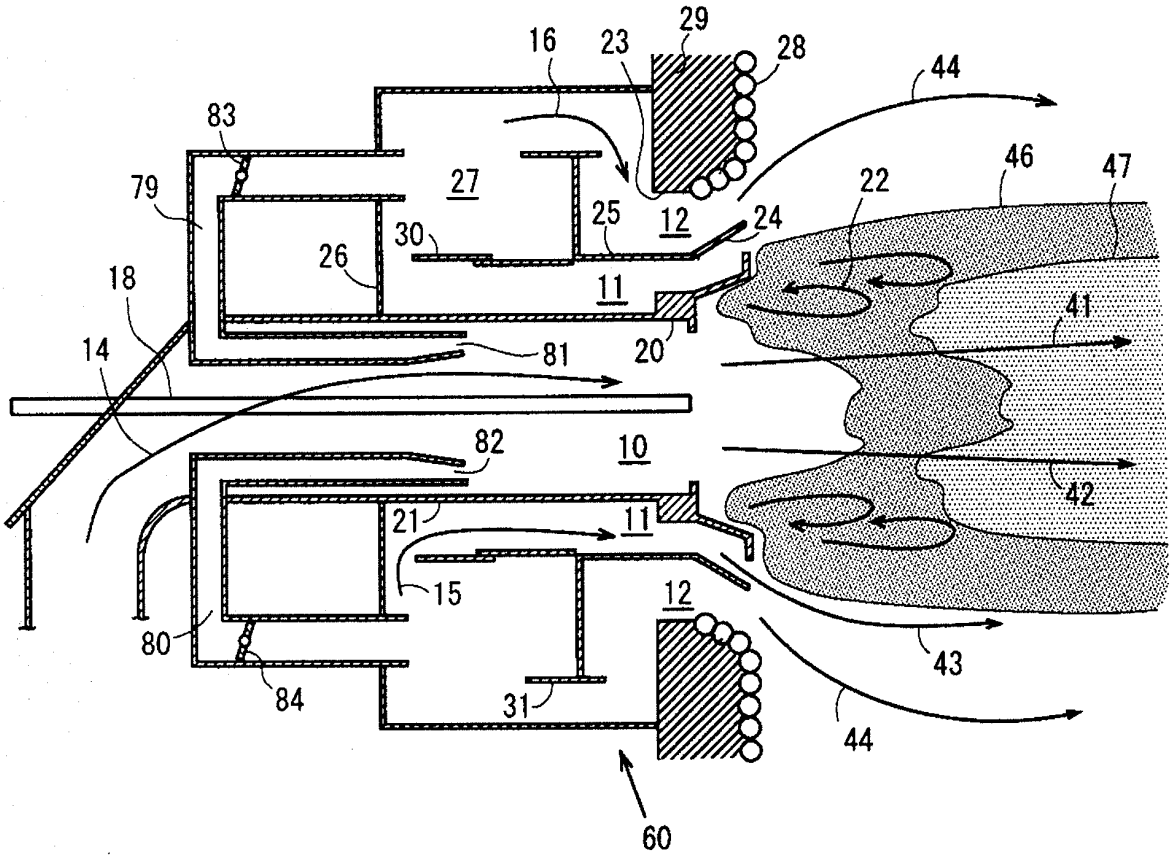

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FIG. 6

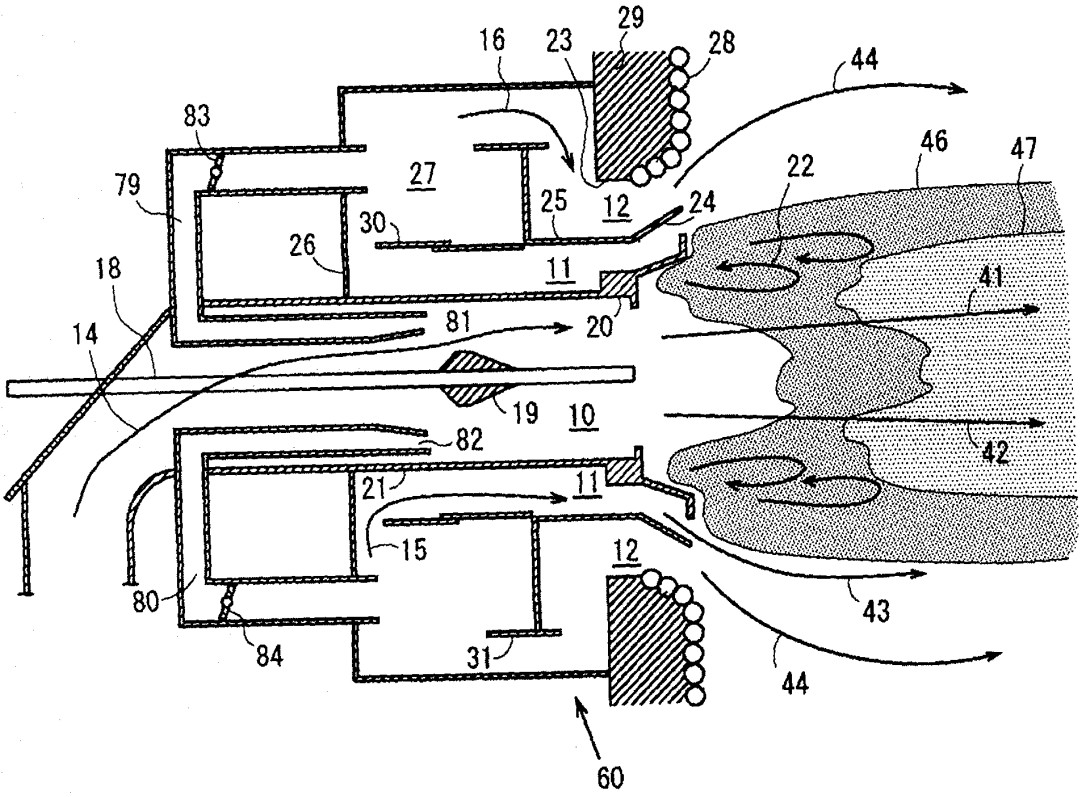

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FIG. 7

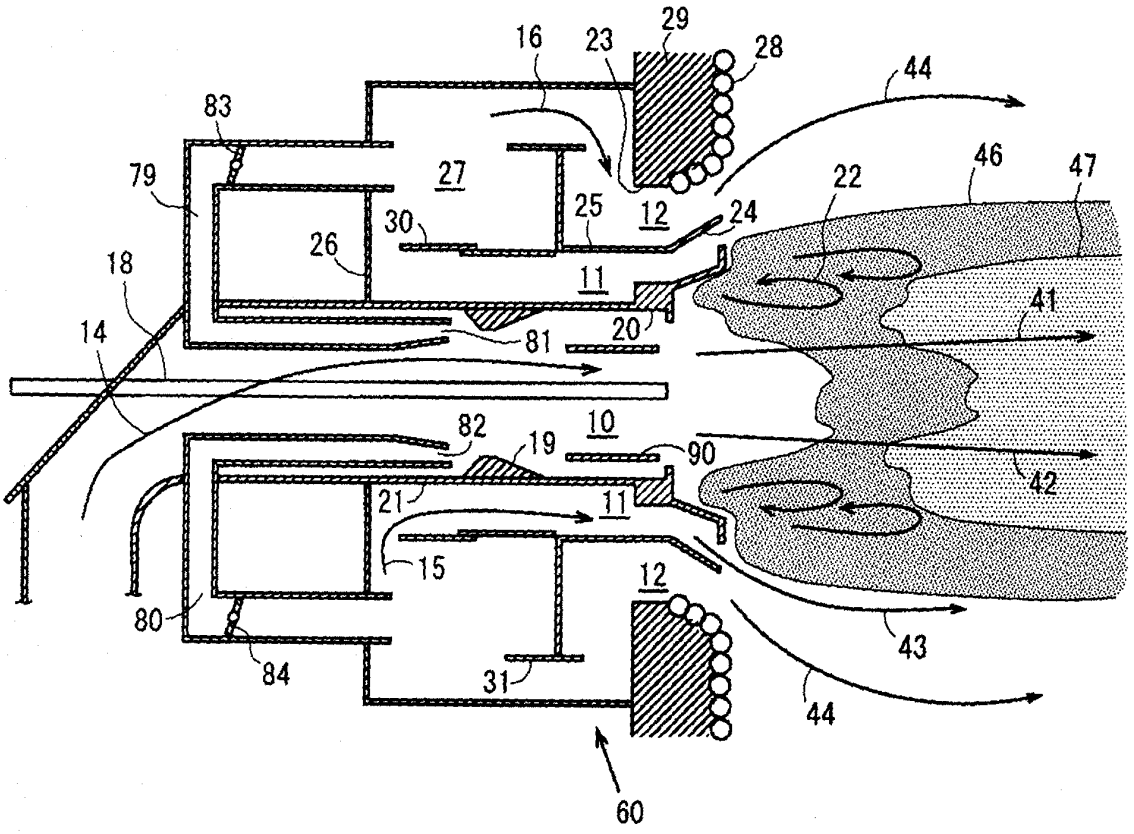

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FIG. 8

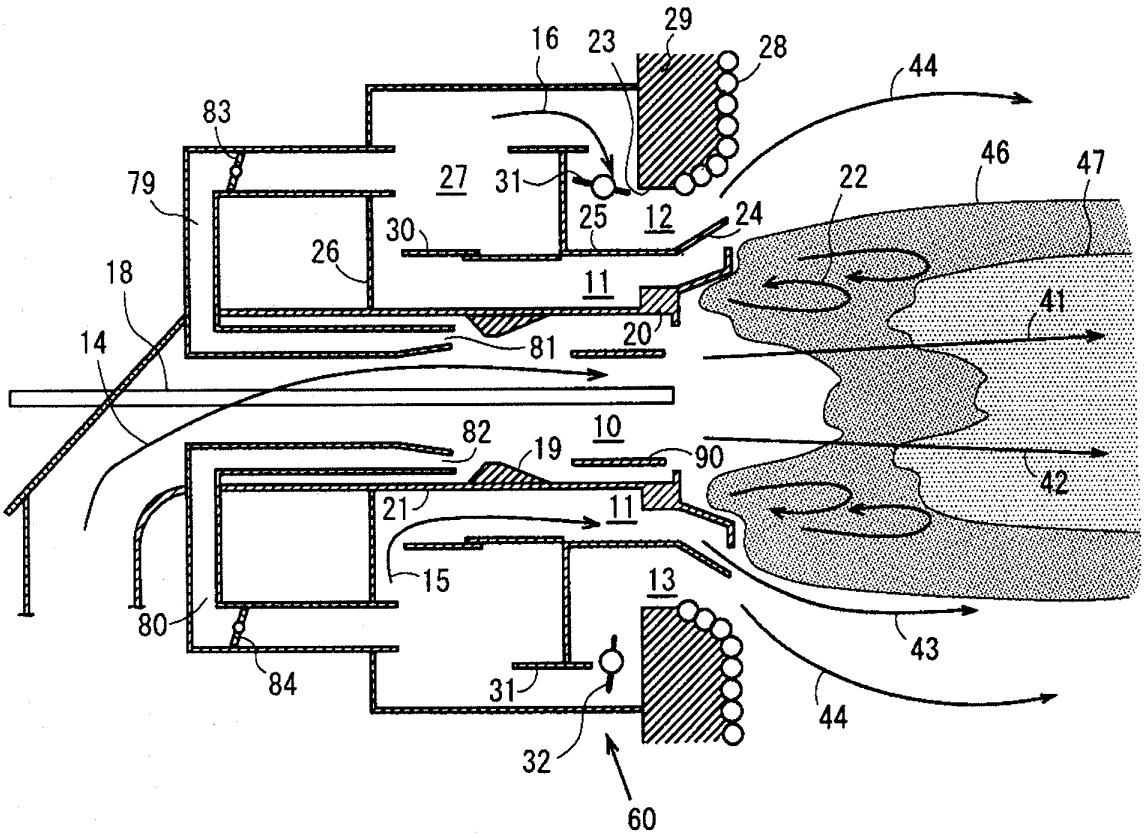

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FIG. 9

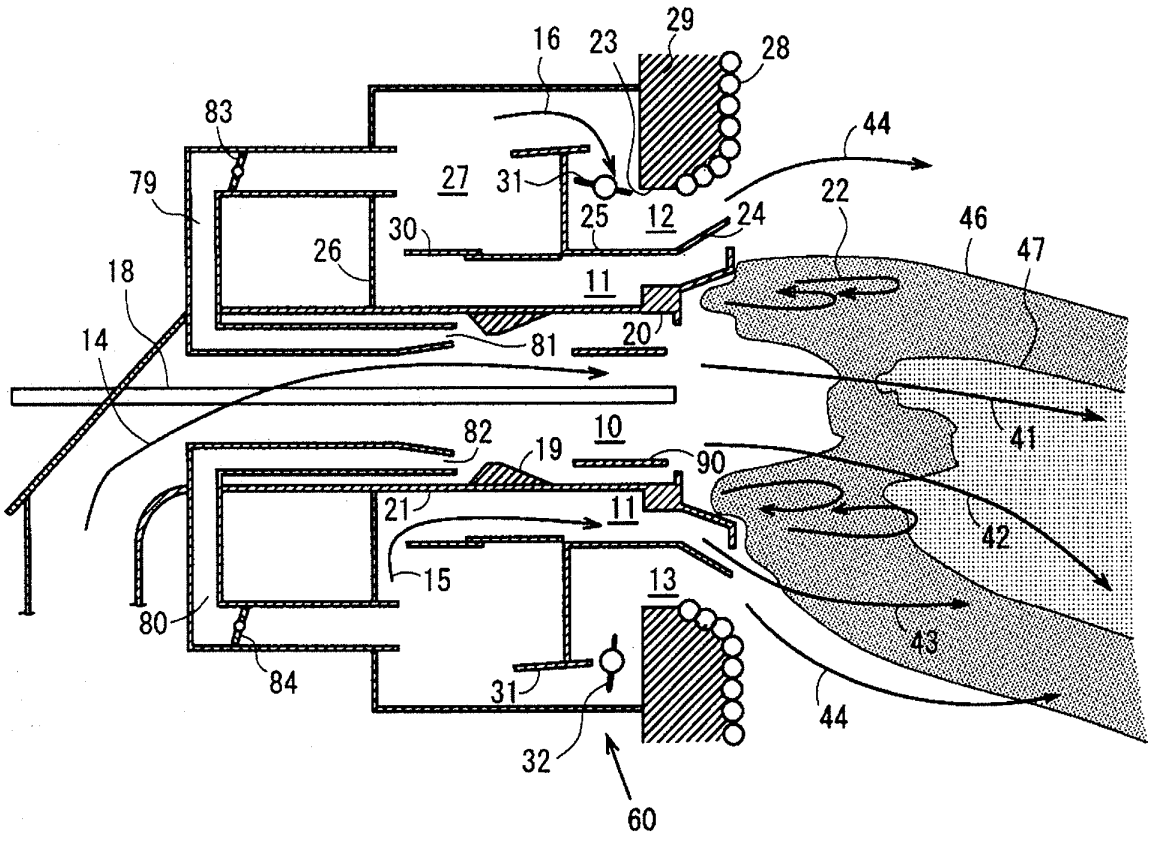

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FIG. 10

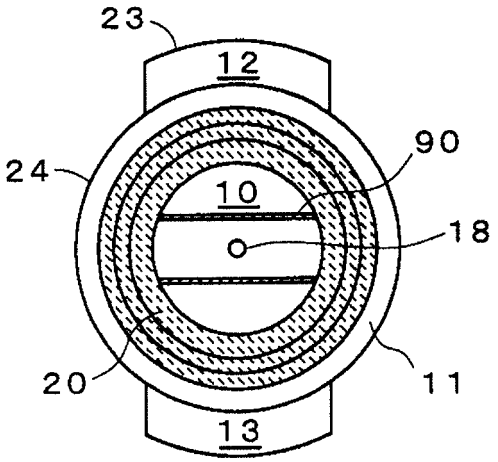


FIG. 11

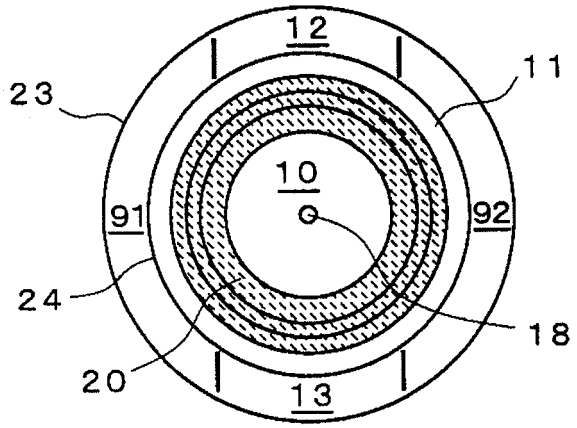


FIG. 12

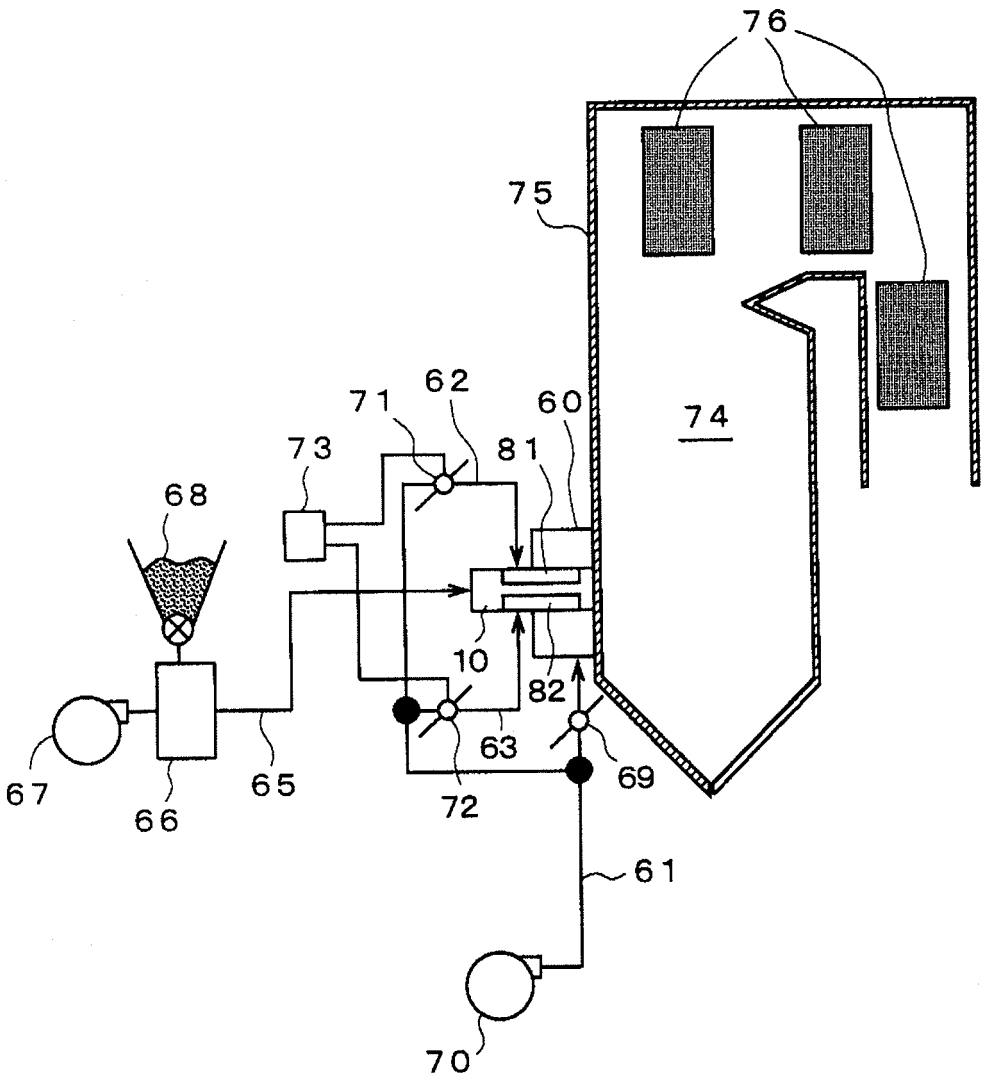
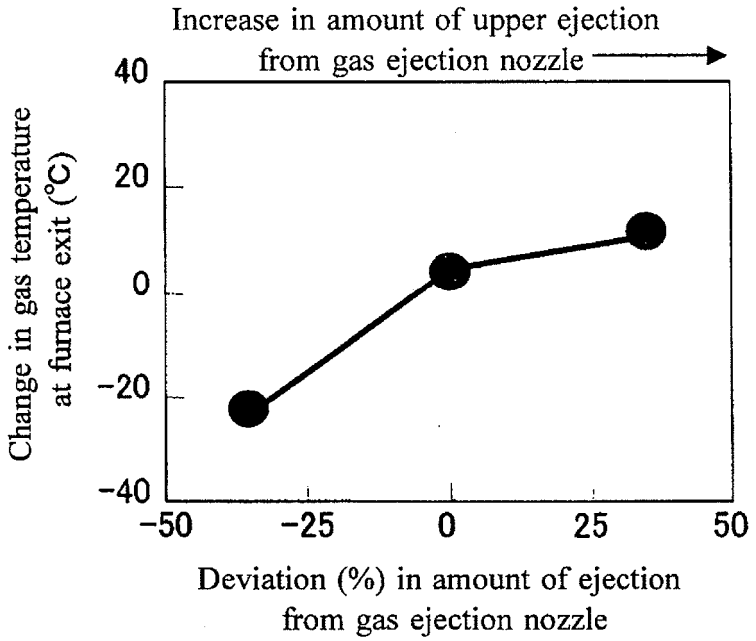


FIG. 13


Increase in amount of upper ejection
from gas ejection nozzle
Change in gas temperature
at furnace exit (°C)
40
20
0
-20
-40
-50
-25
0
25
50
Deviation (%) in amount of ejection
from gas ejection nozzle

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/054045

A. CLASSIFICATION OF SUBJECT MATTER
F23D1/00(2006.01)i, *F23C99/00*(2006.01)i, *F23N5/02*(2006.01)i

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)
F23D1/00, F23C99/00, F23N5/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2008
Kokai Jitsuyo Shinan Koho 1971-2008 Toroku Jitsuyo Shinan Koho 1994-2008

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-240227 A (Hitachi, Ltd.), 27 August, 2003 (27.08.03), Column 6, lines 38 to 50, column 11, line 24 to column 21, line 31; Figs. 1 to 12 & US 2004/0211345 A1 & US 2005/0092220 A1 & US 2007/0079736 A1 & EP 1312859 A1 & CA 2410725 A	1-9,11
Y	WO 02/12791 A1 (Babcock-Hitachi Kabushiki Kaisha), 14 February, 2002 (14.02.02), Fig. 1 & US 6715432 B2 & EP 1306614 A1	1-9,11

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
09 May, 2008 (09.05.08)	20 May, 2008 (20.05.08)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/054045

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2005-140480 A (Hitachi, Ltd.), 02 June, 2005 (02.06.05), Fig. 1 & US 2005/0120927 A1 & EP 1530005 A2 & CA 2487215 A	1-9,11
Y	JP 62-276309 A (Hitachi, Ltd.), 01 December, 1987 (01.12.87), Page 2, upper right column, line 15 to lower right column, line 19; Figs. 1 to 2 (Family: none)	8-9,11

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 6439136 B **[0006]**
- JP 2002147713 A **[0006]**
- WO 0212791 A **[0006]**