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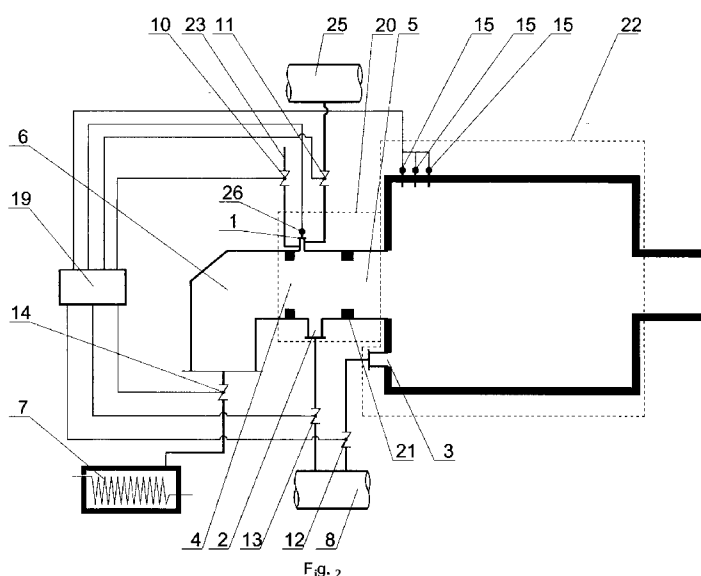
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(54) Title: THE METHOD FOR BURNING FUEL IN COMBUSTION CHAMBERS OF METALLURGICAL FURNACES, STEELMAKING FURNACES, HEATING BOILERS AND POWER BOILERS AND FUEL BURNING SYSTEM IN COMBUSTION CHAMBERS OF METALLURGICAL FURNACES, STEELMAKING FURNACES, HEATING BOILERS AND POWER BOILERS.

(57) Abstract: Method for burning fuel, wherein in order to obtain temperature T necessary for initializing the F2 operating mode, first the combustion chamber is preheated with burning products from the F1 operating mode to temperature T_k and the air supplying the burner is preheated in the heat exchanger to temperature T_{AIR} , which can range from the ambient temperature to 450°C, and maximally to 600°C. This relationship is defined by $T = 1/2(T_k + T_{AIR})$, after meeting this condition the secondary fuel is supplied at the F2 operating mode. At the F2 operating mode, the fuel is supplied through one lance with a nozzle, from which a stream flows parallel to the stream of burning mixture of the air and fuel from the first burning segment and exhaust gases, mixes and burns together causing the extension of the flame, extension of the burning time, even distribution of temperatures in the combustion chamber and low emission of toxic compounds.

The method for burning fuel in combustion chambers of metallurgical furnaces, steelmaking furnaces, heating boilers and power boilers and fuel burning system in combustion chambers of metallurgical furnaces, steelmaking furnaces, heating boilers and power boilers.

The subject of the invention is the method for burning fuel in combustion chambers of metallurgical furnaces, steelmaking furnaces, heating boilers and power boilers and the system for execution of this burning.

In the Polish application no. P 3501 12 there was presented a method for decreasing the use of fuel and emission of CO_2 and NO_x in burning processes with highly preheated air, in which highly preheated air, at the temperature higher than the fuel self-ignition temperature, is provided into the combustion chamber through nozzles located at the distance twice bigger than the double diameter of the highly preheated air nozzle hole but not bigger than five times the diameter of this nozzle hole,

whereas it is preferred if, for example, for burning natural gas the air is preheated air up to the temperature of at least 850 °C, and for burning heating oil and coal dust the air is preheated up to the temperature of at least 550 °C. Moreover, it is preferred if the volumetric fraction of the oxygen in the outlet exhaust gases is included in the range from 0.25 to 3.0 %. A furnace to realize this method with a high temperature air heater has at least two ceramic regenerators of the "honeycomb" type, which work alternately: while one is being heated with hot exhaust gases in order to accumulate energy, the other one is heating the burning air flowing through it up to the temperature of at least 850 °C in the case of gas burning, and up to at least 550 °C in the case of heating oil or coal dust burning, and then the functions are reversed.

In the American patent description no. US 5403181 there was presented a burning method with low emission of NO_x in which basic fuel is injected from the outside into an air stream for burning, initiating the first burning stage, which generates a cylindrical main flame covering the air stream for burning. Separately injected secondary fuel is captured by the main flame, which reduces NO_x emerging in the main flame, as a result of the second burning stage, which is created by the contact of the secondary fuel with the air carried by the main flame. This solution allows to reduce the content of NO_x in exhaust gases. In the embodiment of the method presented in this description two stages are provided: stage one, in which a full amount of the air for burning is injected through a burner throat, supply of fuel and injection of fuel from the edge of the air stream towards this air stream, the first primary burning of the fuel in order to create a

cylindrical main flame surrounding the air stream, in the second stage the secondary fuel is supplied and injected from the outside towards the previously generated flame and undergoes secondary burning with a part of the air penetrating through the main flame, thus creating the secondary flame. Initially, the air is surrounded by the main flame up to the moment when the secondary fuel is being injected. Immediately after the injection towards the supplied air, the secondary fuel is surrounded by the main flame mentioned above, which leads to their contact and reduction of NO_x , and then another secondary burning process takes place.

In the burning method with low emission of NO_x air is supplied to the system and used for burning of the primary fuel, which is carried into the first burning segment at the F1 operating mode, where the primary fuel is injected into the air stream and then the remaining part of the air penetrating the combustion chamber is submitted to the secondary burning by means of the secondary fuel, which is injected into the chamber at the F2 operating mode. The proportion of the fuel used in the F1 and F2 operating modes in relation to the air can be defined at any rates: 90 - 30 % of the fuel F2 to 10 - 70 % of the fuel F1. In the first burning stage, where the main fuel is injected in the direction from the peripheries of the air stream flowing in the throat towards this air and it is ignited by a pilot burner; the burning process as well as the process of forming a cylindrical main flame begins. The flame surrounds the air. In order to create such a cylindrical flame, two or more main fuel nozzles should be applied and preferably, they should be located at even distances on the internal surfaces around the throat. At this moment, some

part of the air undergoes primary burning, creating the cylindrical main flame and the other part of the air flows further inside the cylindrical flame. Then, at the F2 operating mode, the secondary fuel is injected towards the flame from the nozzles, which are located outside the main flame. At the F2 operating mode, the secondary fuel, immediately after being injected, meets the main flame, which separates it from the air stream flowing inside the flame. Then, the main flame is deprived of a significant portion of oxygen and the injection of the secondary fuel results in the reduction of NO_x in the main flame at the place where both fuels get in contact. Then, at the lower part of the stream, far from the main flame, at the F2 operating mode, the secondary fuel gets into contact with the remaining air that has gone through the main flame, which results in the secondary burning. At this stage, the secondary flame is created inside the combustion chamber. Therefore, the air, supplied through the throat, is shielded in its external part from the secondary fuel by the main flame, which provides certainty that NO_x contained in the main flame is reduced due to the share of the secondary fuel, then the air is completely burnt up only by the secondary fuel. Assuring the adequate distribution of temperatures and, which is closely related to it, the distribution of the heat stream in the zones of modern industrial furnaces is one of the basic requirements that modern burning systems have to meet nowadays. The burning technology called HiTAC, for High Temperature Air Combustion, is one of the burning technologies which fulfills the condition mentioned above, and which is documented in literature and confirmed by industrial applications. The HiTAC burning technology is used in HRS regenerative

burners equipped with ceramic regenerators. These burners are used for heating industrial furnaces. Although the HRS burners are supplied with the air of ambient temperature, inside them the air is heated in the regenerative resources up to the temperature of around 100°C lower than the combustion chamber temperature, and the F2 operating mode is initialized if the temperature in the combustion chamber is higher than 750°C, thus it is the minimum temperature measured at the wall of the combustion chamber, resulting from the standard PN-EN 746-2, and consequently the air temperature behind the regenerator is higher than 650 °C. In the HiTAC technology, the temperature for transition from the F1 mode to the F1/F2 mode or the F2 mode depends on many factors, including the type of fuel and the temperature of the air supplied to HRS burners.

The subject matter of invention is that for obtaining temperature T necessary for initializing the F2 operating mode, first the combustion chamber is preheated with products of the combustion at the F1 operating mode to temperature T_k and the air supplying the burner is heated in the heat exchanger to temperature T_{AIR} , which can range from the ambient temperature to 450°C, and maximally to 600°C, this relationship being defined by $T = 1/2(T_k + T_{AIR})$, after fulfilling this condition the secondary fuel is supplied at the F2 operating mode. At the F2 operating mode fuel is supplied through one lance with a nozzle, from which a stream flows parallel to the stream of burning mixture of air and fuel from the first burning segment and exhaust gases, mixes and burns together causing

the extension of the flame, the extension of the burning time, even distribution of temperatures in the combustion chamber and low emission of toxic compounds, especially very low emission of NOx.

In the system according to invention, the first segment of the burning system is in the form of a cylinder, inside which there is placed at least one pilot burner and at least one primary fuel nozzle situated on the axis parallel to the tangent of the cross section of the cylinder perpendicularly to the long axis of the combustion chamber, the first segment being connected with the supply air chamber at one side and at the other side it has a throat finished with a fire pipe, which is connected with the inlet of the second burning segment, with a mounted lance with a nozzle of the secondary fuel and at least one sensor for burning system temperature.

In the first embodiment of the system, the combustion chamber is connected with the air heater through an control damper.

In the second embodiment of the system, in the first burning segment, all primary fuel nozzles are connected together with a fuel supplier by means of an control damper.

In the third embodiment of the system, in the first burning segment, each pilot burner is connected with a gas fuel supplier by means of cut-off valves connected with a control unit, and a UV sensor is also connected with the control unit.

In the fourth embodiment of the system, in the second burning segment, there is one lance with a secondary fuel nozzle which is connected with a fuel supplier through an control damper.

In the fifth embodiment of the system, in the first burning segment, each pilot burner is connected with an air supplier through an control damper.

In the sixth embodiment of the system, the temperature sensors are connected with a unit controlling the work of control dampers of the primary fuel nozzle, control damper of the secondary fuel nozzle, control damper of the duct supplying air to the air chamber.

The invention was developed as a result of research, observations and theoretical considerations. It was observed that before fuel is ignited in the combustion chamber the air stream that is injected into the combustion chamber mixes strongly with hot products of the burning process which actually are in the combustion chamber. The volumetric proportion of the air sucked by the stream to hot exhaust gases was defined at the minimum level of 1:1, that is to say, 1m³ of air is sucked and mixed with 1m³ of hot fumes. The temperature of such a mixture equals, simply speaking, the mean temperature of these temperatures $T = 1/2(T_k + T_{AIR})$. For example, if temperature T_k in the combustion chamber is 1200°C, then the fuel injection into the combustion chamber will be possible, for instance, at the air temperature $T_{AIR} = 300^\circ\text{C}$.

Thanks to this solution it is not necessary to use only burners equipped with ceramic regenerators in the HiTAC burning technology, but it may be also used in the case of furnaces with central, metal recuperators, in which the temperatures of the air supplied to burners are usually within the range of 250°C to 450°C, and in extreme cases up to 600°C. Such definition of the criteria resulted in the development of a new

family of burners called HTB (High Temperature Burner), which, similarly to HRS burners (High-cycle Regenerative System burners), use the HiTAC burning technology but have a simplified construction and are significantly smaller.

The method and system with new HTB burners according to invention allows to reduce the emission of NO_x , CO, CO_2 , to obtain even distribution of temperatures in the zone and in the load and a remarkable extension of the life expectancy of the combustion chamber lining.

Application of the method according to invention results in the extension of the flame by 10% to 30% in comparison with the flame in burners with two lances. This result is achieved thanks to the extension of the mixing distance, along which a fuel particle meets an oxidant particle.

The invention is showed in a drawing, in which Fig. 1 shows the concept of the method according to invention together with the illustration of the burning process, Fig. 2 - a schematic diagram of the system, Fig. 3 - a cross section of the burner of the burning system.

Fig. 1 shows processes occurring during the burning by the method of the invention, wherein: A denotes preheated air, B - exhaust gases, F1 - fuel supplied in the first burning stage, F2 - fuel supplied in the second burning stage, F1+A - burning mixture of the air and fuel from the first burning stage, surrounding the air stream, F1+A+B - burning mixture of the air, fuel from the first burning stage together with exhaust gases, F2+F1+A+B - burning mixture of the air, fuel from the first and second

burning stages together with exhaust gases, F2+A+B - burning up mixture of the air, fuel from the second burning stage together with exhaust gases, 1- pilot burner, 2 - fuel nozzle of the first burning segment, 3 - lance with fuel nozzle of the second burning segment, 24 - zone of strong reduction of NO_x, AIR - air.

In this method, in order to achieve temperature T necessary for initializing the F2 operating mode, the combustion chamber is first heated with the burning products from the F1 operating mode up to the temperature T_k and the air supplying the burner is heated in the heat exchanger up to the temperature T_{AIR} , which can range from the ambient temperature to 450°C, and maximum to 600°C, this relationship being defined by $T = 1/2(T_k + T_{AIR})$, after meeting this condition the secondary fuel is supplied at the F2 operating mode. At the F2 operating mode, the fuel is supplied through one lance with the nozzle 3, from which the air stream flows parallel to the stream of burning mixture of the air and fuel from the first burning segment and exhaust gases, mixes and burns together causing the extension of the flame, extension of the burning time, even distribution of temperatures in the combustion chamber and low emission of toxic compounds, especially very low emission of NO_x.

In the case of HTB burners, the criterion for initializing the F2 operating mode is defined as the average of temperatures in the combustion chamber and the air supplied to the burner and it amounts to: 640°C for propane **C₃H₈** and 690°C for methane CH₄, which, with the combustion chamber heated to adequate temperatures above 750°C, allows to supply HTB burners with the air at the temperature from 0°C to 600°C. The

combustion chamber is heated from the ambient temperature up to 750°C by means of the F1 operating mode. The work in the F1 operating mode consists in the ignition of the mixture of the fuel and air by the pilot burner **1** inside the main burner, in its throat. The mixture ignited in the burner throat goes through the fire pipe 5 to the combustion chamber and heats it. After reaching the set point temperature, which depends on the combustion chamber temperature measured at the combustion chamber walls, the temperatures of the supplied air and the type of the fuel, the F2 operating mode is initialized. Since this moment, apart from being supplied through nozzles of the F1 operating mode, the fuel is also supplied with one lance with a nozzle 3 of the F2 operating mode, for each installed and working burner. The outlet of the fuel from the lance with a nozzle 3 is located at a particular distance from the fire pipe 5 of the burner, from which the flame and burning products of the F1 operating mode of the burner get out. The air flowing from the fire pipe 5 of the burner while working in the F2 operating mode should move at the speed of around 10 to 100 m/s. The direction of the supplied fuel stream is favorably parallel to the stream of the supplied air and mixture of exhaust gases and the flame. By changing the angle of the fuel supply in relation to the stream of the mixture of the air, exhaust gases and flame, the length of the flame may be controlled. However, it should be noticed, that such changes also influence the quality of the burning process and distribution of temperatures inside the combustion chamber. As regards the emission of NO_x and the distribution of temperatures, the optimum way of supplying

the fuel in relation to the stream of air, exhaust gases and flame is when the two streams are parallel.

The burning system according to invention, which comprises a supply air chamber 6, two-segment burning system, primary fuel nozzles 2, one lance with the secondary fuel nozzle 3, a pilot burner 1, an air heater 7, a fuel supplier 8, a gas fuel supplier 25, control dampers 10, 11, 12, 13, 14, temperature sensors 15, UV sensor 26 and a control unit 19, is characterized in that the first segment 20 of the burning system is in the form of a cylinder, inside which there is placed at least one pilot burner 1 and at least one primary fuel nozzle 2 situated on the axis parallel to the tangent of the cross section of the cylinder perpendicularly to the long axis of the combustion chamber, the first segment 20 being connected with the supply air chamber 6 at one side and at the other side it has a throat 21 finished with a fire pipe 5, which is connected with the inlet of the second burning segment 22, with a installed lance with a nozzle 3 of the secondary fuel and at least one temperature sensor 15 for burning system. In the first embodiment of the system, the combustion chamber is connected with an air heater 7 through an control damper 14.

In the second embodiment of the system, in the first segment of the burning system, all primary fuel nozzles 2 are connected together with a fuel supplier 8 by means of an control damper 13.

In the third embodiment of the system, in the first segment of the burning system, each pilot burner 1 is connected with a gas fuel supplier 25 by means of cut-off valves connected with a control unit 19, and the UV sensor 26 is also connected with the control unit 19.

In the fourth embodiment of the system, in the second segment of the burning system, there is one lance with a fuel nozzle 3 which is connected with a fuel supplier 8 through an control damper 12.

In the fifth embodiment of the system, in the first segment of the burning system, each pilot burner 1 is connected with an air supplier 23 through an control damper 10.

In the sixth embodiment of the system the temperature sensors 15 are connected with a control unit 19 monitoring the work of control dampers 13 of primary fuel nozzles 2, control damper 12 of secondary fuel nozzle 3, control damper 14 of the duct supplying air to the air chamber 6.

The invention may be applied where emphasis is put on the high quality of burning, low emission, energy saving and improvement of product parameters. HTB burners are installed in heating furnaces in rolling mills as side or longitudinal burners. It is also possible to use HTB burners in tank furnaces, in combustion chambers of metallurgical furnaces, steelmaking furnaces, heating boilers and power boilers.

Thanks to the invention supplying fuel only through one lance with a nozzle allows to extend the length of the flame, which further leads to the increase in the actual burning area. The increase of the burning area results in extension of the forming time of the fuel and air mixture, which enables to mix the emerging mixture better and more thoroughly with burning products, which are already in the combustion chamber as a result of inner recirculation. This procedure has its effect in a more even

distribution of temperatures in the flame, and further in the whole combustion chamber. Conducting burning process according to this procedure leads to:

- Increased life expectancy of lining of the furnace.
- Increased efficiency of the furnace as the time necessary for making temperatures in the heated load shortens.
- Increased quality of products. Lack of local over and under heating of the load.
- Reduction in power resources demand calculated by one kilogram of the product.
- Reduction in the emission of nitrogen oxides NO_x .
- Reduction in the emission of carbon dioxide CO_2 .
- Possibility to install burners in objects, where the installation of two-lance systems has not been possible so far due to the lack of room.
- Reduction in manufacturing costs of the installation as it has been simplified.
- Increase in reliability of the system as it has been simplified.

Claims.

1. The method of burning fuel in the combustion chambers of power boilers, metallurgical furnaces, steelmaking furnaces, heating boilers and power boilers **characterized in that** for obtaining temperature T necessary for initializing the F2 operating mode, first the combustion chamber is preheated with burning products at the F1 operating mode to temperature T_k and the air supplying the burner is preheated in the heat exchanger to temperature T_{AIR} , which can range from the ambient temperature to 450°C, and maximally to 600°C, this relationship being defined by $T = 1/2(T_k + T_{AIR})$, after fulfilling this condition, the secondary fuel is supplied at the F2 operating mode, moreover at the F2 operating mode, the fuel is supplied through one lance with a nozzle, from which the stream flows parallel to the stream of burning mixture of the air and fuel from the first burning segment and exhaust gases, mixes and burns together causing the extension of the flame, extension of the burning time, even distribution of temperatures in the combustion chamber and low emission of toxic compounds, especially very low emission of NOx.

2. The burning system for gas fuel in the combustion chambers of metallurgical furnaces, steelmaking furnaces, heating boilers and power boilers, including the supply air chamber, two-segment burning system, primary fuel nozzles, secondary fuel nozzles, pilot burner, air heater, fuel supplier, gas fuel supplier, control dampers, temperature sensors, UV sensor and control unit is **characterized in that** the first segment (20) of the burning system is in the form of a cylinder, inside which there is at least one pilot burner (1) placed and at least one primary fuel nozzle (2) situated on the axis parallel to the tangent of the cross section of the cylinder perpendicularly to the long axis of the combustion chamber, the first segment (20) being connected with the supply air chamber (6) at one side and at the other side it has a throat (21) finished with a fire pipe (5), which is connected with the inlet of the second segment (22) of the burning system, with an installed lance with a nozzle (3) of the secondary fuel and at least one temperature sensor (15) for burning system.

3. Burning system according to claim 2, **characterized in that** an air chamber is connected with an air heater (7) through an control damper (14).

4. Burning system according to claim 2, **characterized in that** in the first segment (20) of the burning system, all primary fuel nozzles (2) are connected together with a fuel supplier (8) by means of an control damper (13).

5. Burning system according to claim 2, **characterized in that** in the first segment (20) of the burning system, each pilot burner (1) is connected with a gas fuel supplier (25) by means of cut-off valves connected with a

control unit (19), a UV sensor (26) being also connected with the control unit (19).

6. Burning system according to claim 2, **characterized in that** in the second segment (22) of burning system, one lance with a fuel nozzle (3) is connected with a fuel supplier (8) through an control damper (12).

7. Burning system according to claim 2, **characterized in that** in the first segment (20) of the burning system, each pilot burner **(1)** is connected with an air supplier (23) through an control damper (10).

8. Burning system according to claim 2, **characterized in that** the temperature sensors (15) are connected with a control unit (19) monitoring the work of control dampers (13) of primary fuel nozzles (2), control damper (12) of the secondary fuel nozzle (3), control damper (14) of the duct supplying air to the air chamber (6).

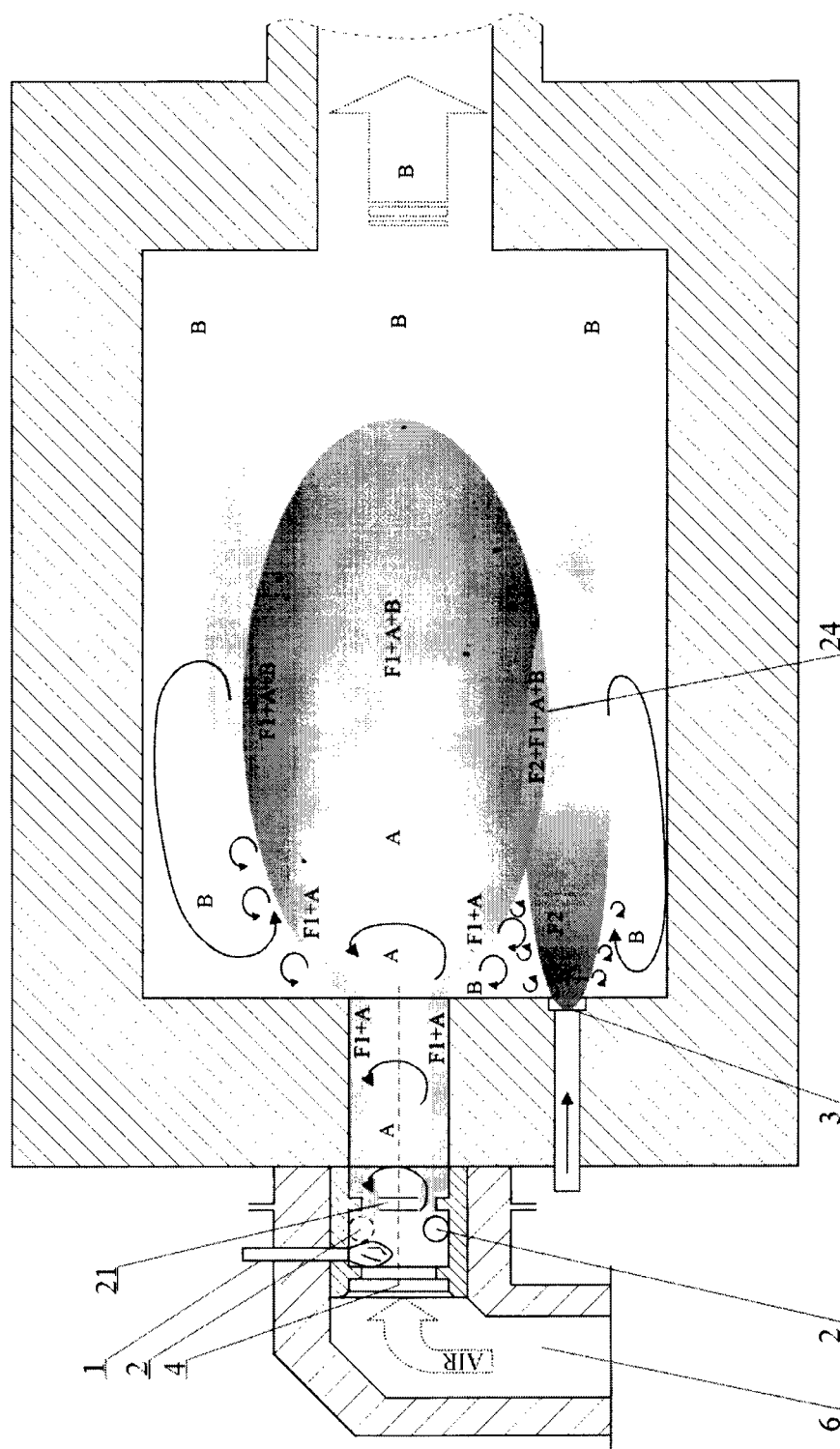


Fig. 1

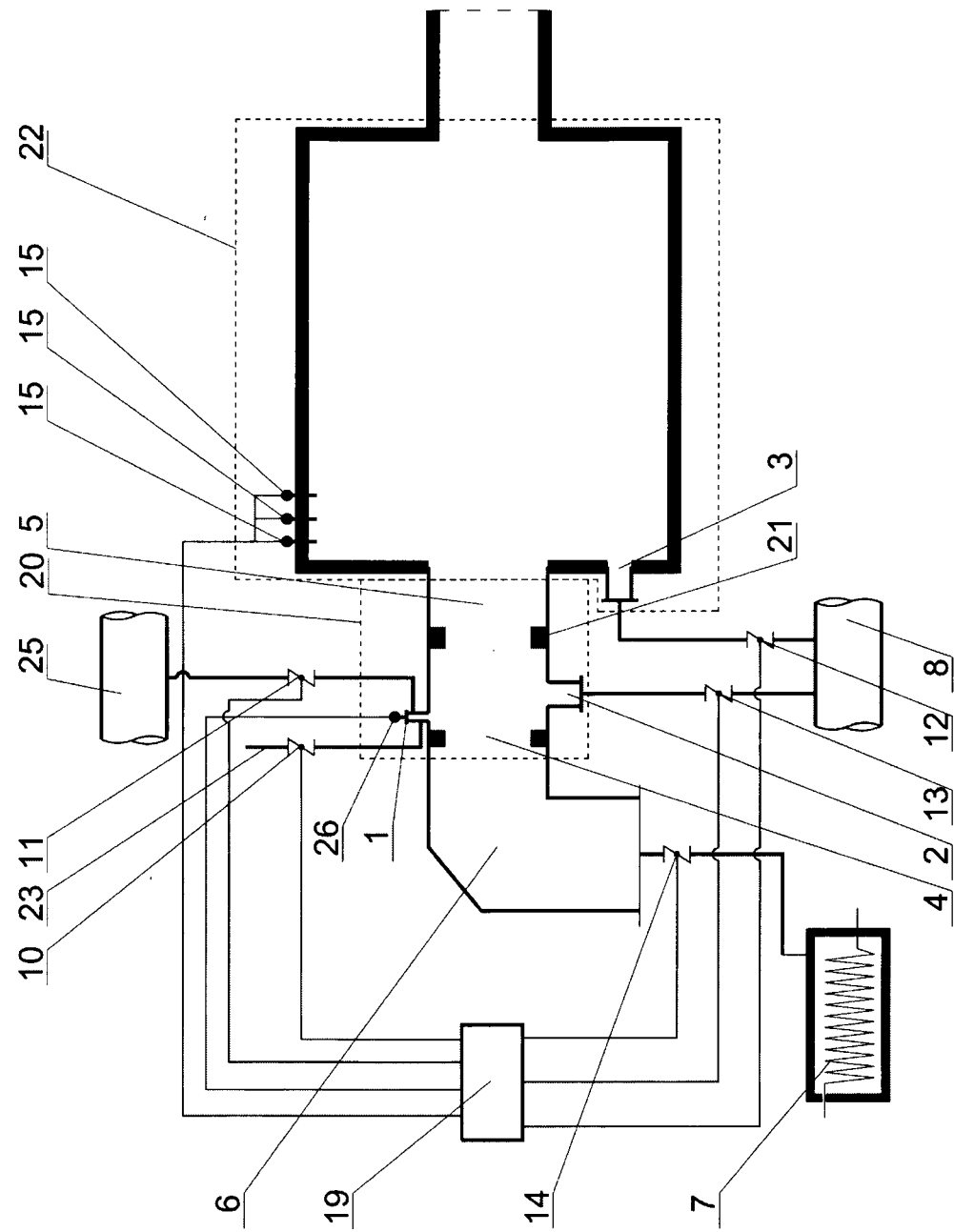


Fig. 2

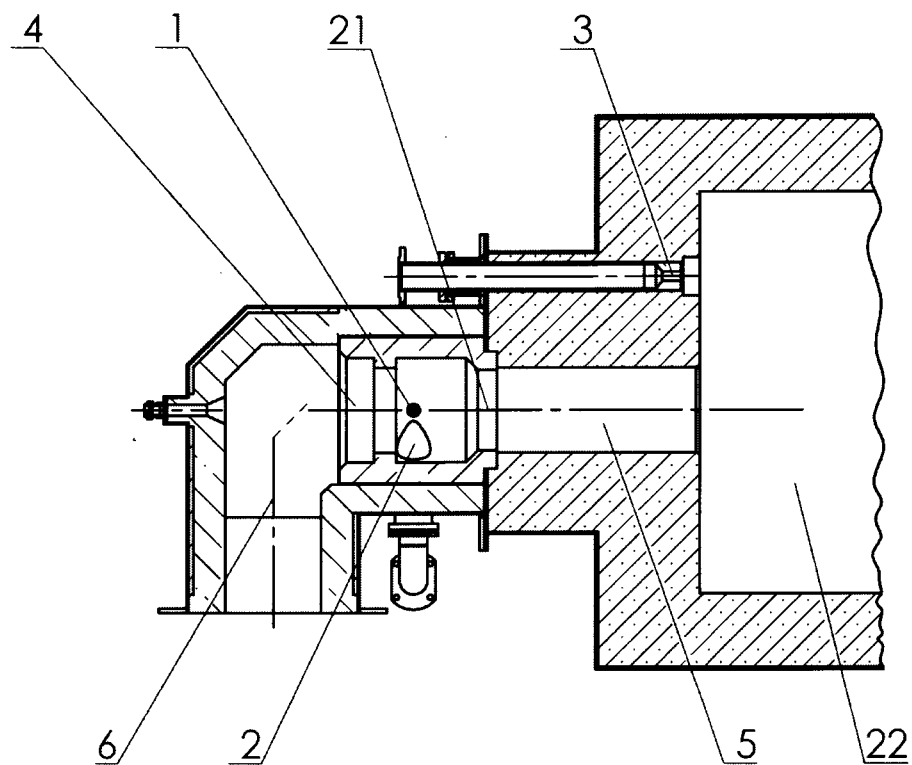


Fig. 3