Development of Low-Volatile Coal Firing Burner

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Bituminous coal has been increasingly used as the main fuel for pulverized coal (PC)-fired boilers for thermal power plants in Japan, and demand for bituminous coal has also increased worldwide. Consequently, PC-fired boilers are now required to use not only bituminous coal but also low-volatile coals like semi-anthracite and anthracite. However, low-volatile coal is difficult to burn stably in existing PC-firing boilers. IHI has developed a new burner that can burn low-volatile coal without using assist oil. The aim of the new burner is increasing emissions of volatile components by recirculating high-temperature furnace gas into the burner. This resulted in improved stable combustion.

1. Introduction

Coal is one of the richest energy sources widely distributed on Earth, and its use will be indispensable in the future to ensure a stable supply of energy by energy mixing. Presently, our country is a prominent importer of coal that largely consists of high-quality bituminous coal. In consideration of the fact, however, that worldwide coal demand will increase due to the rapid economic growth in China and other Asian countries and the production and supply of good-quality coal will decrease in the future, it is considered necessary to accept a wide variety of coal types in addition to bituminous coal.

In our country, the coal-fired power plant is positioned as the base of power supply and load adjusting power, and presently, bituminous coal with its superior combustion characteristics is used as the main fuel for power generation, but the use of low-cost fuel to reduce power generating cost is increasingly demanded. On the other hand, the pulverized coal-firing boiler of utility power suppliers strongly requires technology to cope with low-cost coal and oil coke to reduce the unit cost of power generation.

But most pulverized coal-firing boilers in Japan are designed on the assumption that good-quality bituminous coal is used. For this reason, it is necessary to solve various problems such as boiler efficiency and environmental load performance in order to use coal with properties largely different from those of the design coal. There are also restrictions in operation such as the necessity of support ignition by means of heavy oil.

Despite such technological difficulties, if we can provide low-volatile coal with operability equivalent to that of normal bituminous coal, it will become possible to greatly contribute to the reduction of unit cost of power generation. Under such circumstances, with the target of achieving stable combustion and combustion efficiency of 98.5% or higher for low-volatile coal of volatility of 15% or lower with the burner alone, we developed technology for low-volatile matter solid fuel.

2. Combustion of low-volatile matter solid fuel through high-temperature gas recirculation

In the pulverized coal-firing boiler, the pulverized coal used for fuel goes through the following processes.

(1) Pulverized coal is injected from the burner into the boiler furnace.

(2) The pulverized coal particles are heated by radiation and heat transfer by convection, and the volatile matter is released.

(3) The volatile matter released from the coal is ignited in a gaseous state.

With low-volatile coal, the ignition is difficult and stable combustion is difficult because the volatile content is small and the releasing temperature is high. For such a fuel, it has been clarified that superior combustion characteristics can be obtained for a wide range of coal types including low-volatile coal by raising the temperature of the combustion air.

In this technology, therefore, we promoted the release of the volatile matter and improved the ignitability by circulating part of the combustion gas in the furnace into the burner, thus stabilizing the combustion of the low-volatile matter solid fuel.

Table 1 shows a comparison of characteristics between the low-volatile coal-firing burner called high-temperature gas recirculation burner and the conventional burner (IHI-DF burner) and **Fig. 1** shows the concept. The IHI-DF burner forms internal recirculating flow downstream of the burner by means of rotated combustion air (secondary air) and forms a stable flame by blowing the pulverized fuel in the recirculating flow.

On the other hand, the high-temperature gas recirculation burner forms a high-temperature atmosphere by circulating high-temperature furnace gas in the preheating chamber. The pulverized fuel blown into the preheating chamber releases the volatile matter under the high-temperature atmosphere and ignites, and a stable flame is maintained by the internal recirculating flow formed by the secondary air.

3. Development test equipment and test fuel properties

Figure 2 shows a schematic diagram of the development test equipment. The development test was conducted in the Demonstration Combustion Test Furnace (CFT) of D & D Park (Development and Demonstration Park) in IHI Aioi Works. The burner capacity of the test equipment is 1.2 t/h, and we adopted an indirect combustion system where the fuel is pulverized and then temporarily stored in the pulverized fuel bin. The water-cooling jacket of the combustion furnace is 4.5 m deep and 3.0 m wide and is lined inside with refractory.

Table 2 shows main properties of the test fuel. During development, we used oil coke in addition to coal A (anthracite) and coal B (semi-anthracite) as low-volatile coal. **Table 3** shows the main test conditions. **Figure 3** shows the test fuels plotted on the coal rank table of ASTM (American Society for Testing and Materials Standards).

4. Combustion characteristic of high-temperature gas recirculation burner

Figure 4 shows flame state near the burner throat photographed through the observation window of the side wall of the test furnace when oil coke was fired with the IHI-DF burner. **Figure 5** shows flame state when the oil coke was fired with the high-temperature gas recirculation burner. With the IHI-DF burner in

Table 1 Comparison between high-temperature gas recirculation burner and IHI-DF burner

Item	High-temperature gas recirculation burner	Conventional burner (IHI-DF burner)
Combustion system	Recirculating flow is formed in the burner to promote the release of volatile matter of pulverized coal. Subsequently, combustion is made by internal recirculating flow by means of secondary air.	Combustion is made by charging pulverized coal into the internal recirculating flow by means of secondary air.
Features	· Recirculation of high-temperature gas by involving · Recirculation by turning flow · Higher temperature of primary air · Partial premixing · Control of high-temperature gas recirculation flow of tertiary air	· Recirculation by turning flow · Strong mixing

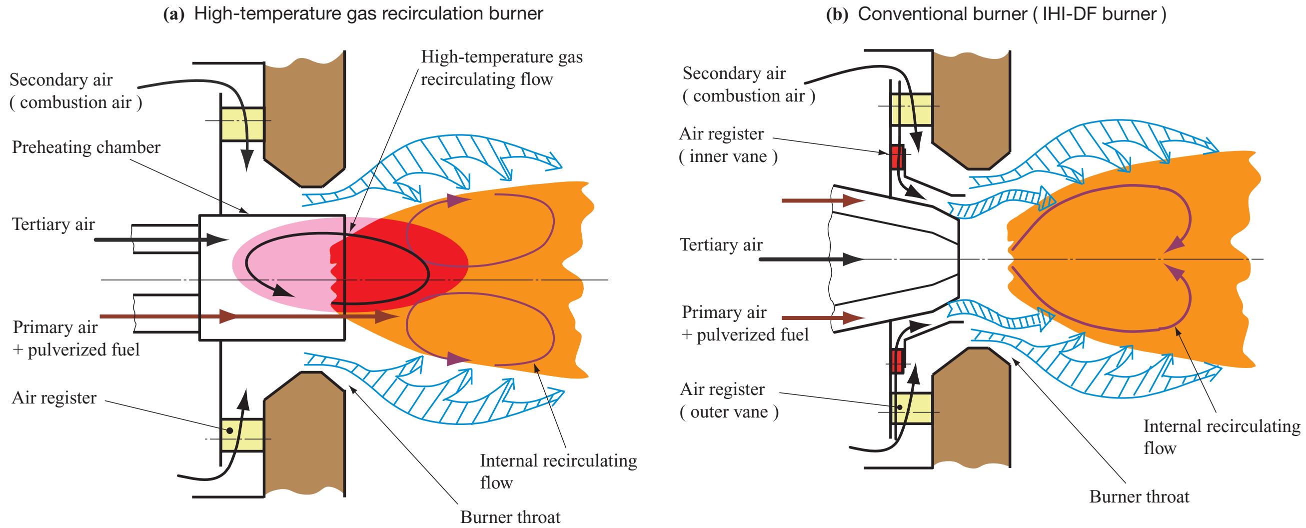

Fig. 1 Concept of high-temperature gas recirculation burner and IHI-DF burner

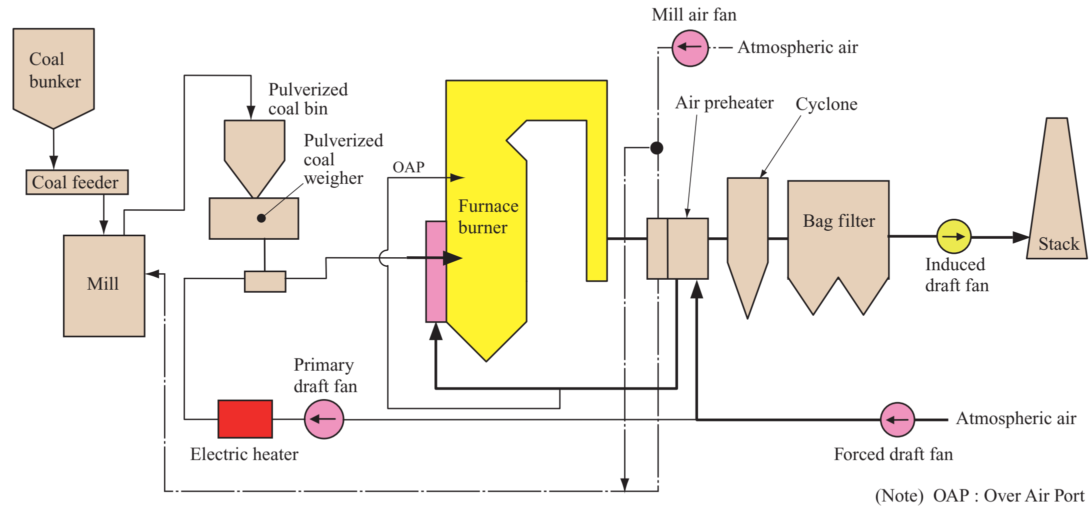

Fig. 2 Schematic diagram of combustion test facility

Table 2 Test coal properties

Item		Unit	Coal A (anthracite)	Coal B (semi-anthracite)	Oil coke
Volatile matter	Dry · mineral matter free	%	10.9	18.9	13.2
Fuel ratio	—	—	9.1	4.4	7.8
Ash	Dry base	%	21.1	15.0	0.8
Calorific value	Dry base	MJ/kg	27.5	27.0	35.4
Nitrogen content	Dry base	%	2.5	1.6	1.2
Sulfur content	Dry base	%	0.4	0.8	2.7

Table 3 Main test conditions

Fuel	Unit	Coal A (anthracite)	Coal B (semi-anthracite)	Oil coke
Combustion rate	t/h	1.2	1.2	1.2
Exhaust gas O_2	%	3.5	3.5	3.5
Staging air ratio	%	0 - 30	0 - 30	0 - 30

Fig. 4, it is bright locally in the throat outlet and ignition occurs, but it is not a stable combustion. With the high-temperature gas recirculation burner in **Fig. 5**, it is bright in almost all the areas of the throat outlet, and stable combustion is obtained.

Figure 6 shows flame temperature distribution when oil coke (**-(a)**) and coal A (anthracite) (**-(b)**) are fired with the high-temperature gas recirculation burner and IHI-DF burner. The measurement was made by inserting thermocouples along the centerline of the burner. The results of both coal A (anthracite) and oil coke reveal that the temperature at the nozzle outlet portion of the high-temperature gas recirculation burner is 800°C or higher, showing more stable ignition than the IHI-DF burner.

Figure 7 shows temperature distribution in the furnace measured through the observation window of side wall of the test furnace with a radiation thermometer. **Figure**

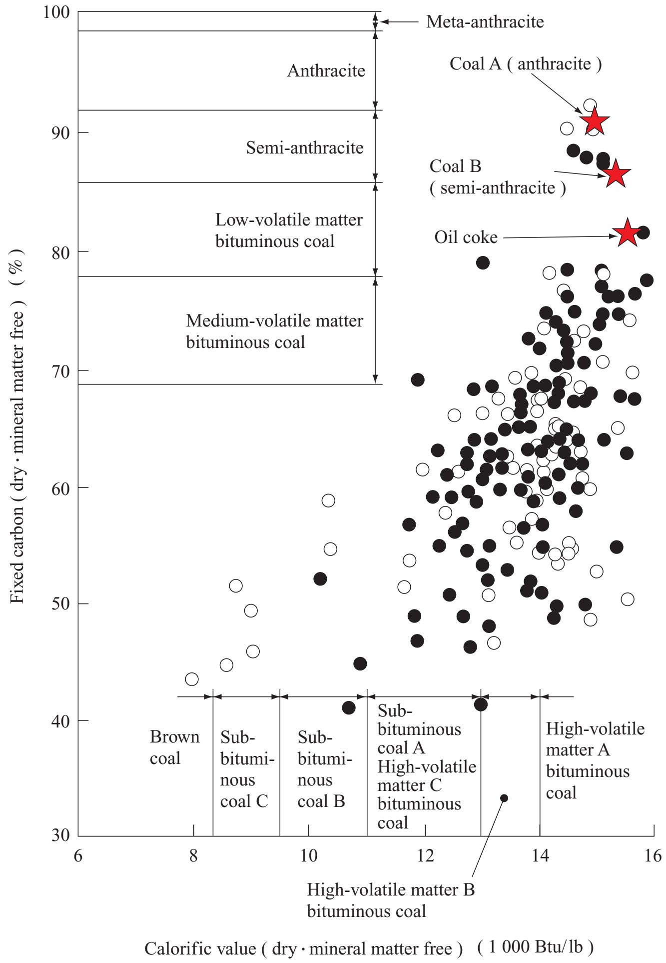

Fig. 3 ASTM classification of coal grade

7 - (a) shows temperature measurement results when the oil coke is fired. In the case of the high-temperature gas recirculation burner, the temperature very close to the burner throat is about 1 050°C, and it is about 200°C higher than about 850°C for the conventional burner

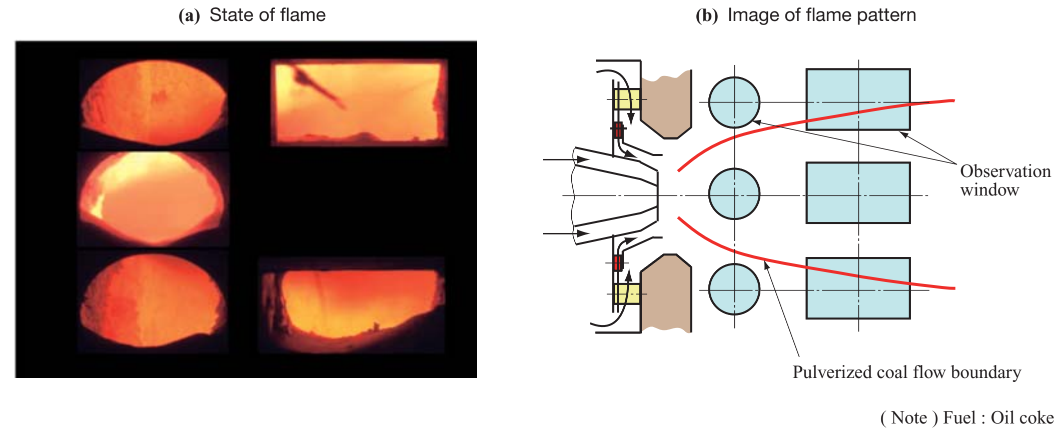

Fig. 4 Flame state using IHI-DF burner

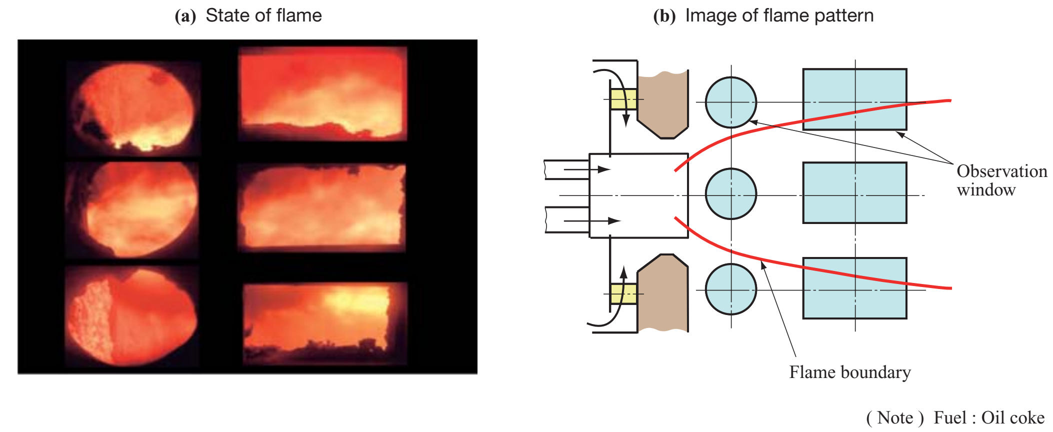

Fig. 5 Flame state using high-temperature gas recirculation burner

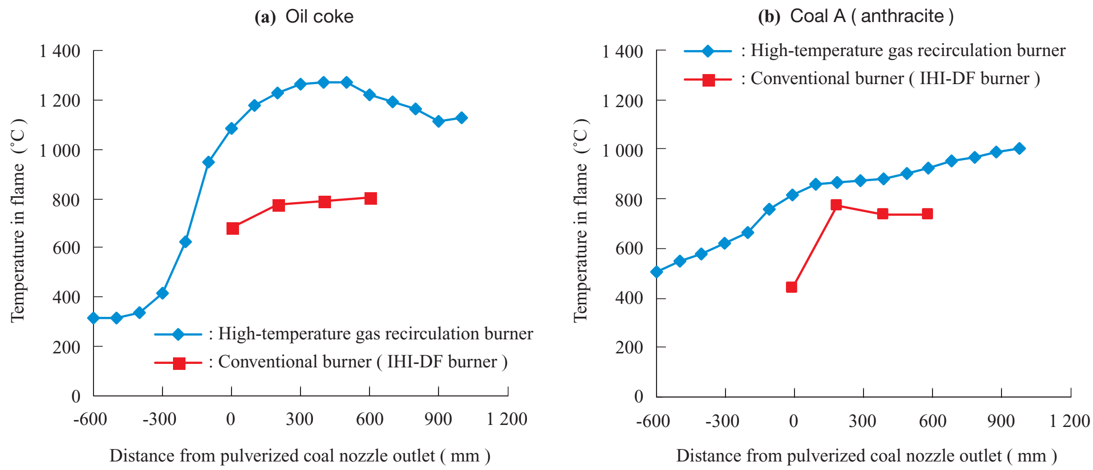

Fig. 6 Flame temperature distribution along the burner centerline

(IHI-DF burner). With the high-temperature gas recirculation burner, the temperature rises as it leaves the throat, and it peaks at the position of about 2 000 mm. In combination with the observation inside the furnace, this means that the combustion is completed at the position of about 2 000 mm from the burner.

On the other hand, with the IHI-DF burner, temperature rises after 2 000 mm away from the throat, and high-temperature continues to near the furnace wall, and the combustion mainly occurs near the rear wall of the furnace.

Figure 7 - (b) shows the measurement results when coal A (anthracite) was fired. The anthracite has less volatile content than oil coak and is difficult to burn. For this reason, the temperature distribution with the IHI-DF burner changes from 800°C to about 900°C from the burner throat to near the rear wall of the furnace, showing less combustion than the oil coke.

With the high-temperature gas recirculation burner, on the other hand, the temperature is about 1 000°C near the burner throat as in the case of the oil coke firing, and it is 1 000°C or higher at all the measurement points. The above results show that with the high-temperature gas recirculation burner stable combustion is achieved even when the anthracite is fired.

Figure 8 and **Fig. 9** show combustion characteristics of the high-temperature gas recirculation burner. **Figure 8** shows the results when coal B (semi-anthracite)

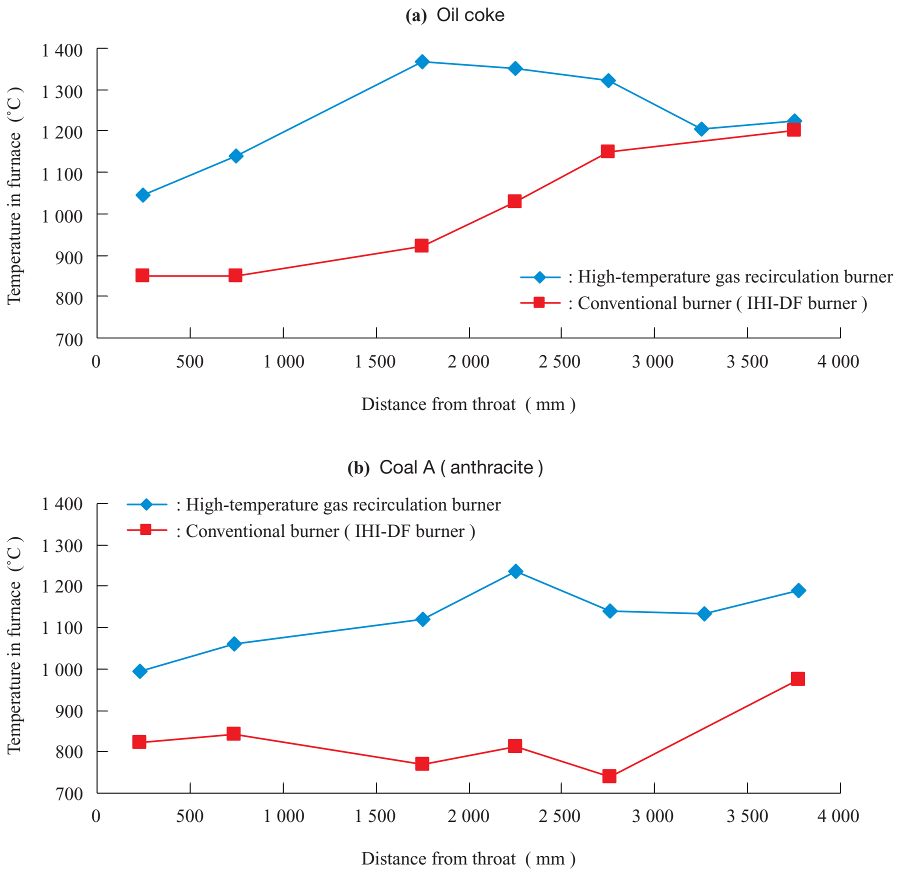

Fig. 7 Temperature distribution in furnace measured via observation windows

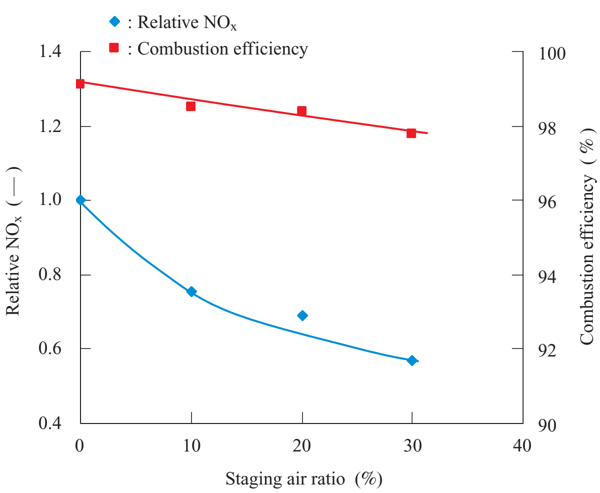

Fig. 8 Combustion characteristics (Coal B)

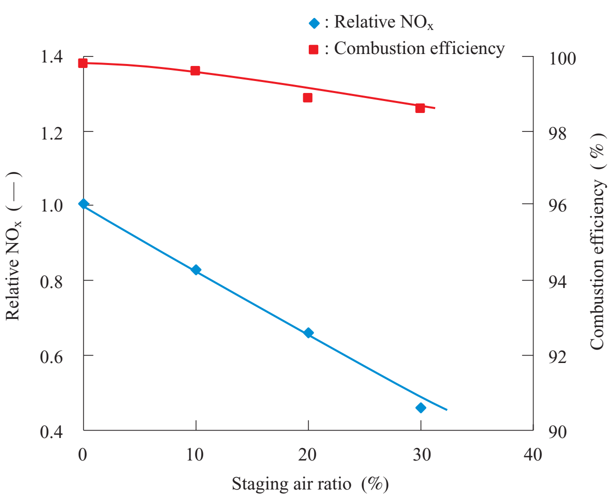

Fig. 9 Combustion characteristics (Oil coke)

was fired, showing NO_x values (relative values) and combustion efficiency against the staging air ratio. Here the NO_x relative values are those under test conditions referring to the staging air ratio of 0%. With the boiler, some tens of percentage of combustion air is input through the Over Air Port (OAP) installed downstream of the burner with the objective of reducing NO_x, and the ratio of air quantity input through the OAP to the total quantity of combustion air is the staging air ratio.

As the staging air ratio increased, NO_x decreased, and NO_x decreased 35% at the staging air ratio of 20%. As the staging air ratio increased, the unburned carbon in fly ash increased and the combustion efficiency decreased, but the target combustion efficiency of 98.5% or more was achieved even at the staging air ratio of 20%. **Figure 9** shows the combustion characteristics when oil coke was fired. As in the case of semianthracite firing, NO_x decreased as the staging air ratio increased, and NO_x decreased about 38% at the staging air ratio 20%. The combustion efficiency at the staging air ratio of 20% also achieved the target of 98.5% or higher.

5. Conclusion

With the target of stable combustion and combustion efficiency of 98.5% or higher with the burner alone for low-volatile coal with volatile content of 15% or less, we have developed technology for low-volatile matter solid fuels. As a result, we developed the following technologies.

(1) We developed a burner that can fire without support ignition low-volatile fuels with volatile content of about 10% to 20%.
(2) We achieved combustion efficiency of 98.5% or higher through combustion of low-volatile fuels with the high-temperature gas recirculation burner.

In the future we will introduce this technology for actual boilers, thereby contributing to stable energy supply.

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