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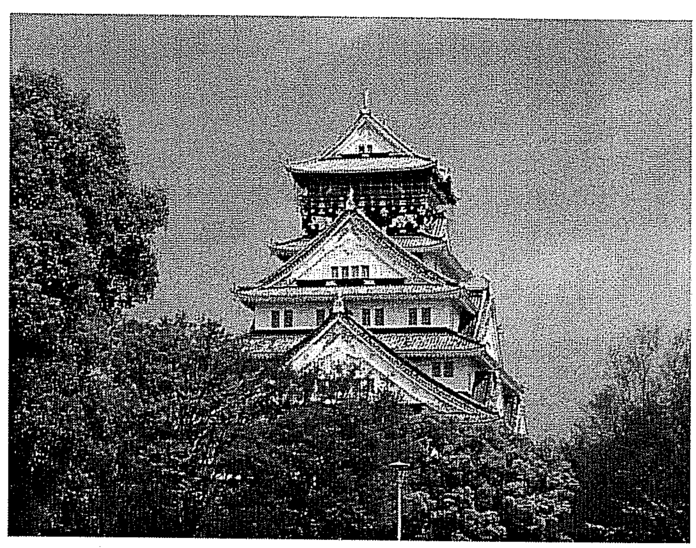

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Effects of coal types on trace elements emission in pulverized coal fired process

Takashi Kuwabara[a], Shinji Kambara[b], Hiroshi Moritomi[b]

[a]Tokyo Electric Power Company, 4-1 Egasaki-cho, Tsurumi-ku, Yokohama, Kanagawa 230-8510, Japan

[b] Gifu University, Graduate School of Engineering, ERES,1-1 Yanagido, Gifu, 501-1193, Japan

Abstract: The partitioning behavior of boron in pulverized coal combustion is investigated to estimate boron concentration in waste water from power station. Boron content in fly ash which was collected at cyclone is analyzed for ten coals. Boron recovery is different from coal types, for example, a significant amount of boron is retained in the fly ash for some types of coal. The recovery is compared with boron content and various properties of the coal and the fly ash. However, almost all the properties have not directly correlation with the boron recovery, although only Ca content in fly ash indicates roughly relationship. To clear effects of coal types on the partitioning behavior of boron, it is important to understand boron vaporization process and coagulation process. Fundamental tests for boron vaporization also were performed to determine control process of boron behavior during combustion.

1. Introduction

The consumption of steaming coals in Japan reached more than 90 millions tons in 2001, and Japanese electric power companies have been consumed 63 millions tons/year. More than 100 types of coal are imported from overseas. Therefore, evaluation of coal quality impacts on coal-fired power station is the most important issue for operation in power station. The performance of milling, combustibility, NOx/SOx emission, and power generation cost for various types of coal has been studied, which can choose coals having low power generation cost and environmentally friendly coals[1)].

Recently, trace elements emission in waste water from a coal fired power plant, fluorine, boron and selenium, are regulated in Japan. The trouble is that some coals are over the regulation even if their species content is low in a coal. Many research have been published for the behavior of trace elements during combustion[2)], however, the knowledge of boron behavior during combustion is very few. Goodarzi and Swaine described that boron in coal is released during combustion[3)], and boron in coal is associated with organic matter and its content is influenced on environment of coal deposition[4)]. In the combustion tests using simple drop tube furnace, Kambara et al.[5,6)] reported that boron in coal is not released during early stage combustion, but almost all boron is released during final stage combustion. However, the partitioning of boron and coal quality impacts on it are unknown.

In this paper, to predict the boron concentration in waste water from coal fired power station, the retained and/or coagulated boron in fly ash after combustion for various coal types is investigated by using pilot scale turbulent flow furnace. Sample coals are prepared 10 wide variety coals, such as sub-bituminous and bituminous coals from Indonesia, China, South Africa, and Australia. The dominant factor controlled the difference of boron recovery in fly ash was discussed.

2. Experimental

2.1. Coal properties

Table 1 shows proximate and ultimate analysis for 10 sample coals. Fuel ratio range is from 1.0 to 2.2

and boron content range is from 25 ppm to 245 ppm, which have wide coal rank and boron range. In previous work[6], boron content in a coal was analyzed for 108 coals, which contained the range from 4 ppm to 245 ppm. As shown in Table 1, Indonesian, Chinese and American coals have high boron content, on the other hand, Australian coals have low boron content.

Table1 Proximate, ultimate and boron analysis for 10 sample coals

Coal	Proximate[wt%,db]			Fuel ratio	Ultimate[wt%,daf]					B
	Ash	Volatile	FC	[-]	C	H	N	S	O	[mg/kg,db]
IND-BD	3.3	49.4	47.4	0.96	74.75	4.57	1.29	0.04	19.35	101
IND-AB	2.2	49.1	48.7	0.99	74.95	4.23	1.10	0.05	19.67	84
PRC-RK	19.8	36.9	43.3	1.17	76.33	4.00	1.69	0.75	17.22	245
PRC-EN	7.7	34.8	57.5	1.65	83.13	5.18	1.50	0.47	17.22	92
PRC-KS	10.3	32.5	57.3	1.76	82.89	5.16	1.48	0.57	9.90	65
SAF-DK	13.5	27.6	58.9	2.14	82.20	4.53	2.04	0.63	10.61	45
SAF-AT	14.4	28.5	57.0	2.00	83.26	4.60	2.03	0.58	9.52	45
AUS-MC	15.1	32.9	51.9	1.58	83.13	5.50	2.13	0.45	8.79	74
AUS-ES	11.5	28.0	60.5	2.16	83.62	4.88	1.77	0.94	8.79	35
AUS-CH	14.7	31.4	53.9	1.72	83.40	5.14	2.04	0.63	8.79	25

2.2. Combustion tests

Combustion tests were carried out with pilot scale turbulent flow combustor. Flow diagram of combustion test facility was shown in Fig.1, and test conditions were shown in Table 2.

The vertical combustor has an inner diameter of 300 mm and a length of 2,500 mm. Pulverized coal (average particle diameter of 35-45 μ m) is loaded into the coal hopper, then it is fed to the furnace by feed rate of 5 kg/h with primary air. Secondary air is added a gyrating movement in window box, and then it led into furnace. Pre-heated two stage air is injected through any OFA (Over Fire Air) port which was built on the side of combustor shell. The OFA factor is defined to quantify the experimental conditions, which is calculated by the distance from burner and the flow rate of OFA.

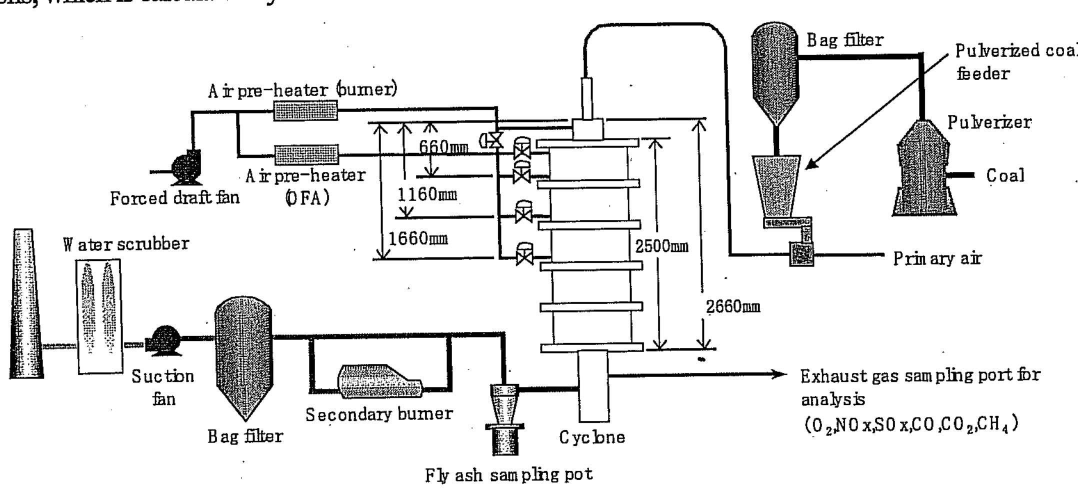

Fig.1 Flow diagram of combustion test facility (feed rate: 5 kg-coal/h)

Fly ash samples after combustion are collected by a cyclone for 1 h. Boron content in fly ash is measured by ICP-MS, and the boron recovery, Brec (%), is decided by the following equation:

$$\mathrm{Brec} = \frac{W_{fc} \times C_{bc}}{W_{fa} \times C_{bfa}} \times 100 \qquad \text{(eq.1)}$$

where W_{fc} is coal feed rate (kg/h), C_{bc} is the boron concentration in coal (mg/kg), W_{fa} is fly ash recovery rate (kg/h), C_{bfa} is the boron content in fly ash (mg/kg).

Table2 Experimental conditions in turbulent flow test furnace

Condition Items	Unit	No-1	No-2	No-3	No-4	No-5
Particle average size	μm	35-45				
Coal feed	kg/hr	4-5 (equivalent to 29,900 kcal/hr)				
Primary air velocity	m/s	19	←	←	←	←
Air ratio	-	1.15	←	←	←	←
OFA factor	-	0	6.7	11.2	16.0	22.3
OFA port No	-	-	3	3	4	4

3. Results and discussion

3.1. Boron recovery of fly ash

Boron recovery of fly ash for 10 coals was shown in Fig.2. Boron recovery is different from coal types, and the rage is 26 % to 69 %. Indonesian coals (IND-AB, BD) having low ash content and high boron content showed the high boron recovery (boron content in IND-AB fly ash was 3,900 mg/kg). Australian coals having low boron content in coal and relatively high ash content showed low boron recovery.

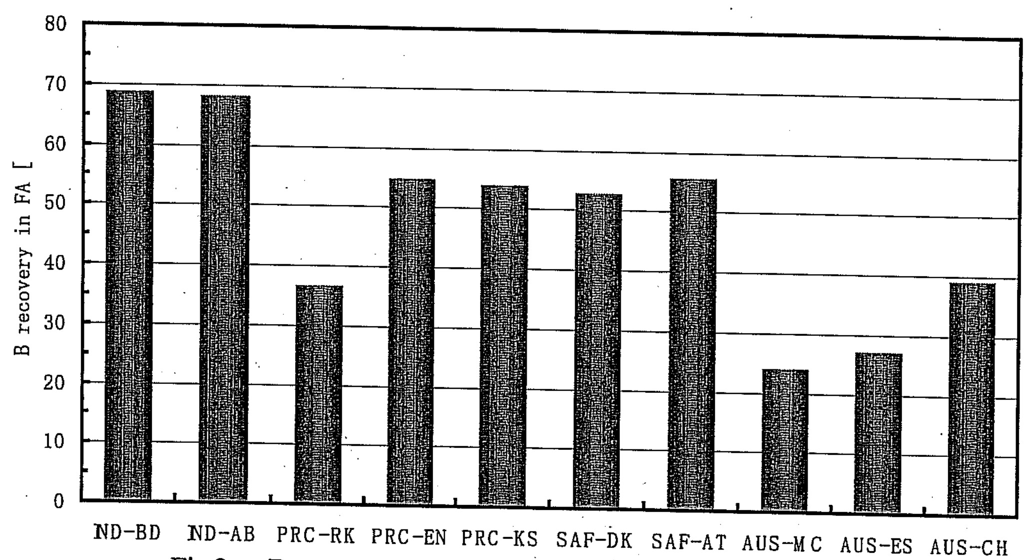

Fig.2 Boron recovery in fly ash after combustion for 10 coals.

3.2. Relation between boron recovery and coal properties

Relation between boron recovery and coal properties is studied to estimate the boron recovery for various coals. Boron content in coal had no correlation with boron recovery. And also Organic properties of coal such as fuel ratio, O/C and H/C were not associated with the boron recovery. As shown in Fig.3, CaO content in ash of parent coal had weak correlation. It is seemed that boron recovery is increased with increasing of CaO content. Same tendency was observed about MgO content. Ca compound may be formed during combustion, however, we can not explain clearly why CaO or MgO effects on boron recovery. The behavior of boron during combustion and after combustion should be studied to be boron partitioning, that is, chemical reaction of boron and ash minerals during combustion and boron adsorption on fly ash surface in post-combustion have to be clear.

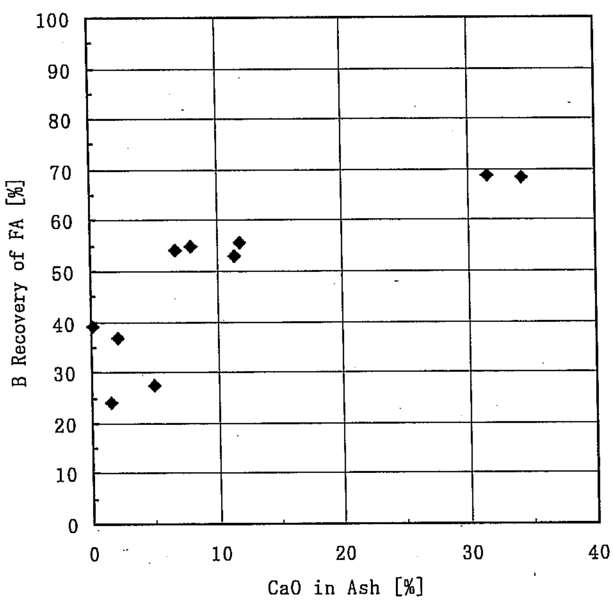

Fig.3 Relationship between boron recovery and CaO content in ash for 10 coals.

4. References

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