

Development of Mercury and SO₃ Control Technology using Gas-Gas Heater

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ABSTRACT

US EPA studies have determined that mercury emissions from coal-fired power plants pose significant hazards to public health and must be reduced. As a part of development of mercury control technology in coal-fired power plants, Hitachi conducted a test using a 1.5MWth Combustion & AQCS (Air Quality Control System) test facility which consists of furnace, SCR, heat exchanger, DESP and Wet-FGD. We have developed a mercury and SO₃ control technology by installing a heat exchanger upstream of the DESP and reducing flue gas temperature below the acid dew point. When the flue gas temperature was reduced to below the acid dew point, the ash accumulation onto the finned tubes of the heat exchanger increased in some cases and resulted in lower heat transfer. Therefore, we studied the ash deposit behavior in the acid condensing atmosphere using the 1.5MWth test facility.

It was confirmed that the ash buildup depended on the alkalinity of the deposited ash, and did not increase drastically if the unreacted alkalinity of the ash was more than 1.0 mmol/g. And if the alkalinity was lower than 1.0 mmol/g, the injection of alkali such as lime into flue gas was effective to prevent the excess ash accumulation.

INTRODUCTION

Babcock-Hitachi has been developing flue gas treatment systems for utility power plants for a number of decades. We are presently developing new air quality control systems (AQCS) to remove hazardous air pollutants (HAP) such as mercury (Hg), sulfur trioxide (SO_3), hydrogen fluoride (HF), particulate matter (PM) and total selected metals (TSM), to comply with recent severe regulations based on the 1990 Clean Air Act Amendments (CAAA). The new AQCS eliminates HAP from flue gas by the combination of "triple action catalyst" (TRACTM)¹, a heat exchanger for flue gas cooling, dust collectors and flue gas desulfurization (FGD) system^{2,3,4}. The heat exchanger is a finned tube flue gas cooler with water as the cooling medium. When the flue gas heat recovered by the heat exchanger is utilized in the plant thermal cycle, it is called a Clean Energy Recuperator (CER); when the recovered heat is used to reheat the saturated flue gas after a wet FGD, it is called a Gas-Gas Heater (GGH).

We have evaluated this new AQCS using 1.5MWth Combustion and AQCS test facility, and the tests achieved over 95% total Hg removal³. A schematic diagram of the test facility is presented in Figure 1 and Figure 2 shows a photo of the same. Coal feed rate was 110-130kg/h (242-286lb/hr). Flue gas temperature at the inlet of DESP was controlled at a temperature ranging from 90 to 160°C (194 to 320 °F) by the GGH. Gas samples were simultaneously taken at six points through the flue gas stream. Symbols from A to F in Figure 1 indicate the sampling points.

Figure 3 shows the mercury removal across the DESP with controlled gas temperature at the inlet of DESP ranging from 90 to 160°C (194 to 320 °F) by GGH. The mercury removal increased as the gas temperature decreased. The mercury removal of the lower sulfur coal was greater than that of the higher sulfur coal, because SO_3 occupied the adsorption sites on the surface of ash particles and mercury adsorption was prevented.

Although a DESP is used in the present study, a fabric filter is expected to have similar or better mercury removal as compared a DESP.

Figure 4 shows changes in SO_3 concentrations in the flue gas from SCR inlet to the WFGD outlet⁴. SO_3 concentrations at the inlet of the DESP decreased dramatically when DESP temperature was reduced from 160°C to 90°C.

When the gas temperature reduced below acid dew point, the ash adhesion onto the finned tube of the heat exchanger increased in some cases and resulted in decreasing efficiency of the heat transfer. Therefore we studied the ash adhesion behavior in the acid condensing atmosphere and its countermeasure using the 1.5MWth test facility.

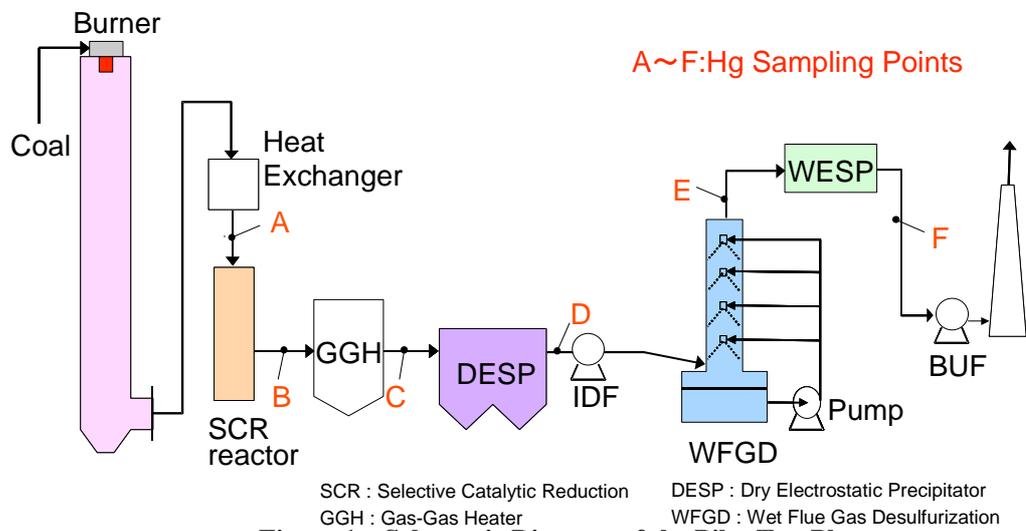


Figure 1 Schematic Diagram of the Pilot Test Plant

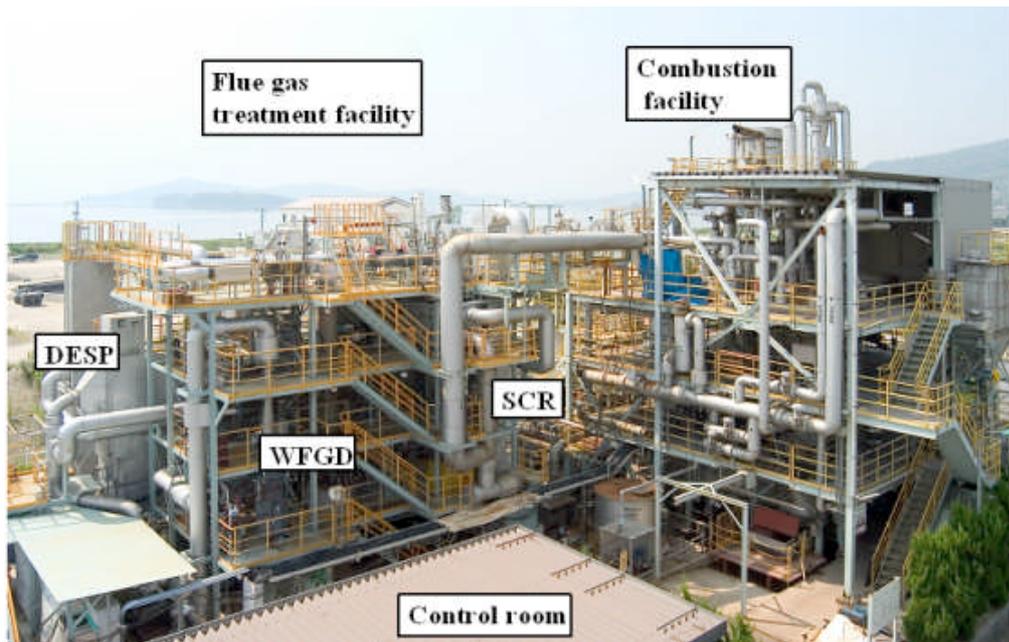


Figure 2 Appearance of the Pilot Test Plant

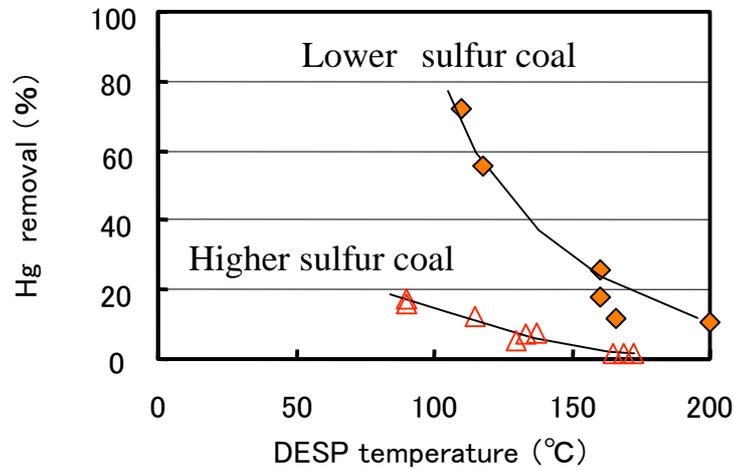


Figure 3 Relationship between DESP temperature and Hg removal across the DESP

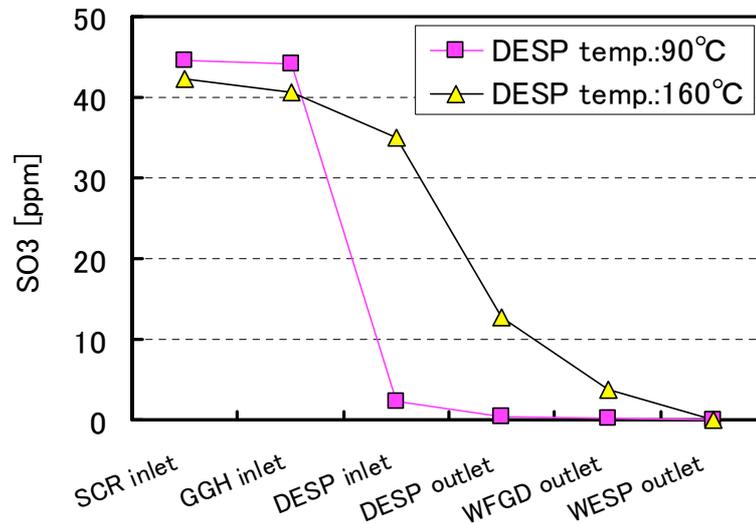


Figure 4 Changes in SO₃ at different DESP temperatures

EXPERIMENTAL APPARATUS

Figure 5 shows the structure of Gas-Gas Heater which was used at the test facility. This heat exchanger consists of many finned tubes and soot blowers are used periodically to remove the ash accumulated on the finned tubes. This structure of GGH used in this test facility is the same as the GGH system in commercial power plants in Japan, which have been operated without any troubles such as the ash deposit or the corrosion.

When this system is applied to a power plant burning eastern bituminous coals which contain high sulfur, the ash deposit onto the finned tubes might increase in some cases and

result in decreasing the efficiency of the heat transfer. In this test, to simulate the flue gas from a high sulfur coal combustion, SO₃ gas was added to the flue gas at the SCR outlet while burning a lower sulfur coal.

The elemental analysis of the coal tested in this study is shown in Table 1. The SO₃ concentration at the GGH inlet was 12ppm.

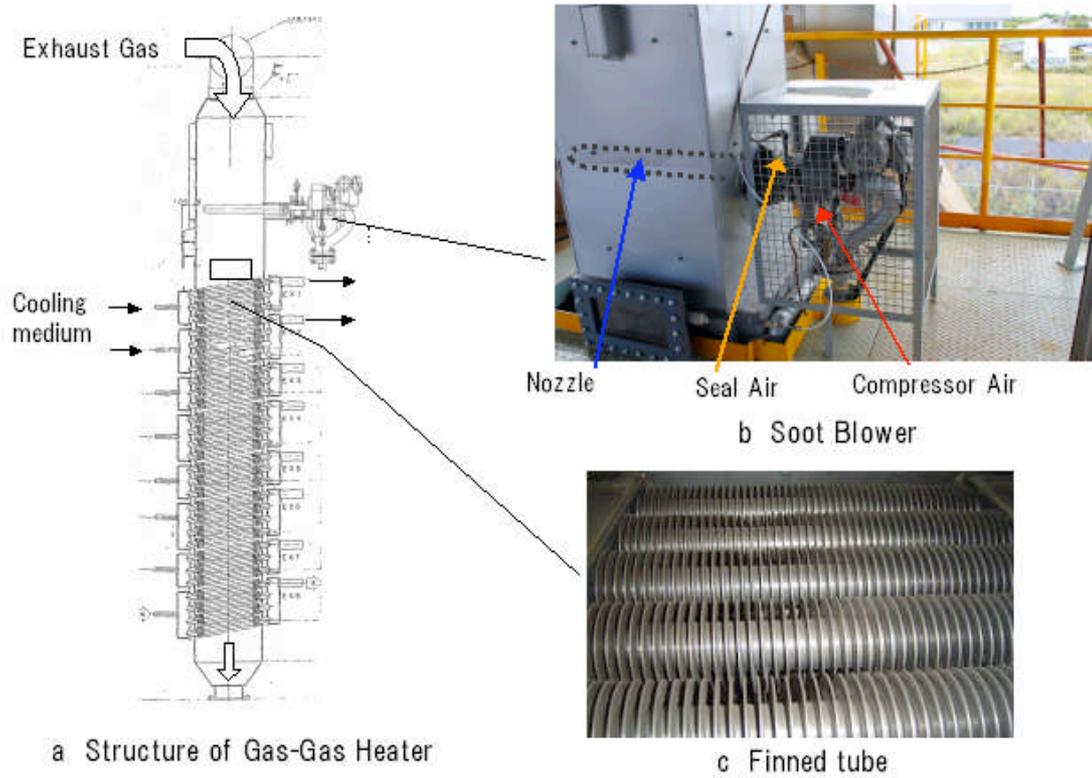


Figure 5 Structure of Gas-Gas Heater

Table 1 Analysis of the Tested Coal (dry basis except moisture)

Proximate analysis	
Moisture (%)	2.4
Volatiles (%)	33.3
Fixed Carbon (%)	55.2
Ash (%)	11.5
Ultimate analysis	
C (%)	73.3
H (%)	4.6
O (%)	8.4
N (%)	1.8
S (%)	0.45

RESULTS AND DISCUSSIONS

Ash Adhesion onto the finned tube

Figure 6 shows the ash deposit behavior onto the finned tubes of GGH when the SO_3 concentration in the flue gas was varied. These photographs illustrate the appearance of the tube surface two hours after soot-blowing. The amount of ash accumulated on the tubes increased with increasing SO_3 concentration in the flue gas.

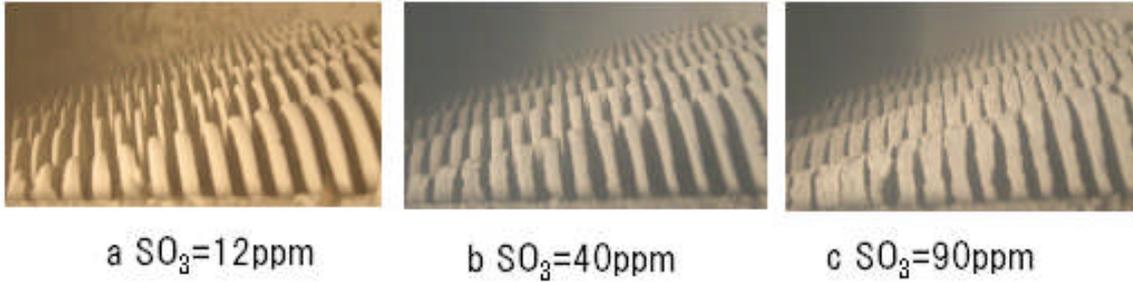


Figure 6 Condition of Finned Tubes

To estimate the ash deposit quantitatively, the overall heat transfer coefficient was calculated from the following equations.

$$Q_1 = A \cdot \alpha \cdot \frac{(T_{gin} - T_{Win}) - (T_{gout} - T_{Wout})}{\ln\left(\frac{T_{gin} - T_{Win}}{T_{gout} - T_{Wout}}\right)} \quad \dots (1)$$

$$Q_2 = W \cdot C_{p(HM)} \cdot (T_{Win} - T_{Wout}) \quad \dots (2)$$

Q_1 : Amount of heat transfer

A : Surface area of heat exchanger

α : Overall heat transfer coefficient

T_{gin} : Gas temperature of GGH inlet

T_{gout} : Gas temperature of GGH outlet

T_{Win} : Heat medium temperature of GGH inlet

T_{Wout} : Heat medium temperature of GGH outlet

W : Flow rate of the heat medium

$C_{P(HM)}$: Specific heat of the heat medium

Figure 7 shows an example of the overall heat transfer coefficient transition. In this test, SO_3 was added into the flue gas and the concentration was elevated to 90 ppm, which was much higher than normal values of eastern bituminous commercial plants.

The overall heat transfer coefficient decreased as the amount of the ash deposit increased with time. And it went back to almost the initial level after operation of the soot blower. The results show that the GGH system can be applied for higher sulfur coal without any problem by soot-blowing.

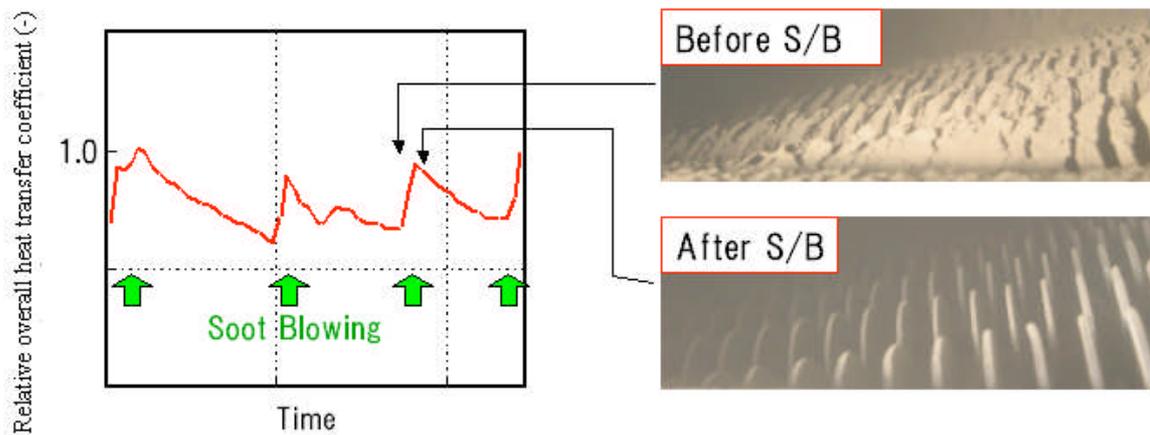


Figure 7 Overall Heat Transfer Coefficient Variation with Time

Figure 8 shows the effect of lime injection to prevent ash adhesion onto the finned tubes. The overall heat coefficient did not drop while the lime was being injected at the inlet of GGH. The behavior of the ash deposit depended on the unreacted alkali concentration in the ash, which was determined by the SO_3 concentration in the flue gas and the alkali constituent in the ash.

Figure 9 shows the relationship between the rate of change in the overall heat transfer coefficient and the alkali concentration in the ash. When the alkali concentration was higher than 1.0mmol/g, the ash accumulation was minimal. However, when the alkali concentration was less than 1.0mmol/g, the ash deposit increased.

Figure 10 shows the unreacted alkali concentrations in four US coals. The alkali component was calculated in the following three cases, CaO , $CaO+MgO$ and $CaO+MgO+Na_2O+K_2O$.

The ash deposit tendency of coal B, C and D were expected to be low, because the alkali concentrations were larger than 1.0mmol/g. In case of Coal A, the alkali concentration in the ash was smaller than 1.0mmol/g, because the sulfur content in ash was high and the CaO content was lower than the other coals. Even in such a case, ash accumulation could be avoided by lime injection.

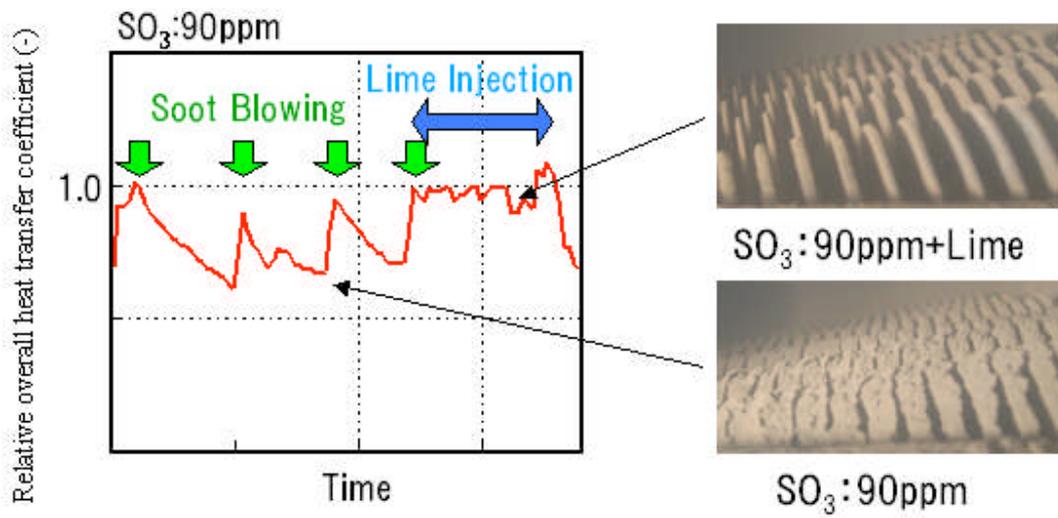


Figure 8 Effect of Reduced the Ash Adhesion by the Lime Injection

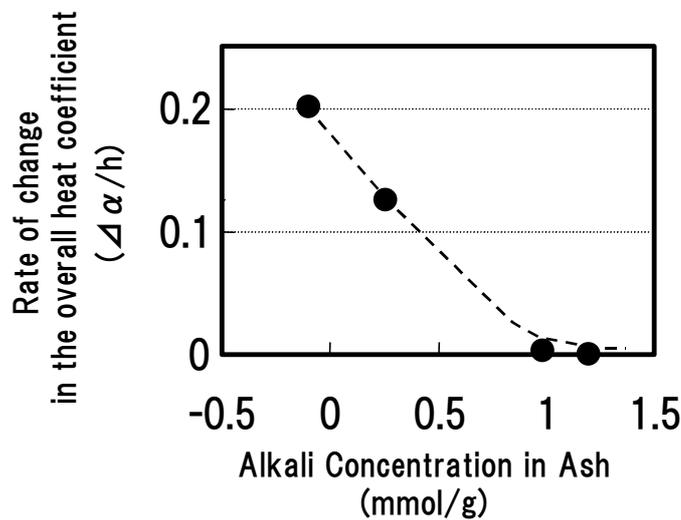


Figure 9 Relationship between Alkali Concentration and Rate of Change in Overall Heat Coefficient

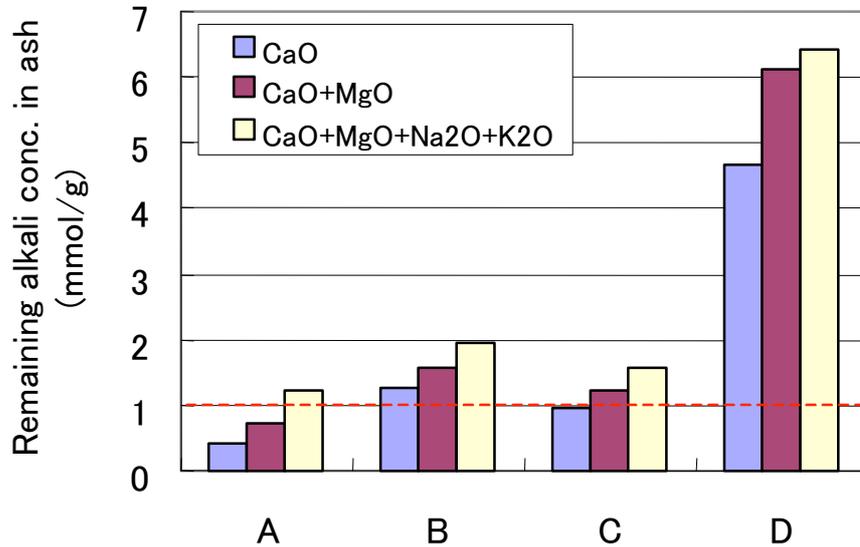


Figure 10 Estimation of Alkali Concentration in U.S. Eastern Bituminous Coals

CONCLUSIONS

The GGH heat exchanger is an important component of the advanced AQCS for the removal of mercury and SO₃. The following results were obtained by examining the ash deposit on the GGH heat exchanger using the combustion and AQCS test facility.

1. Ash deposit onto the finned tubes increased with increasing SO₃ concentration in the flue gas.
2. The GGH system can be applied for higher sulfur coals without excess ash buildup by using soot blower.
3. Ash deposit onto the finned tubes depends on the unreacted alkali concentration in the ash, and did not increase drastically when the alkali concentration of the ash was more than 1.0 mmol/g.
4. When the alkali concentration was lower than 1.0 mmol/g, excess ash deposit was avoided by lime injection.

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