The Effect of Blending Coals on Electrostatic Precipitator Performance

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Key Words: electrostatic precipitation, particulate emission, fly ash, coal, boilers

ABSTRACT

Tarong Power Station, in southern Queensland, Australia, operates 4 X 350 Mwe coal-fired boilers. The boilers fire the local, Meandu Coal from the isolated Tarong Basin. This coal contains 0.3 percent sulfur and 27 percent ash. This ash is 71 percent SiO_2, 27.5 percent Al_2O_3, and 1.9 percent TiO_2, with small amounts of other components. This coal has poor precipitation performance. With water injection, these plants emit 470 mg/Nm^3 of particulate matter. Recent power plant trials blending Meandu with Jeebropilly coal from the Morton Basin (near Ipswich) and Wilke Creek Coal from the Surat Basin (near Dalby) with Meandu Coal have reduced the emissions to near 100 mg/Nm^3.

The objective of this study was to identify the causes of the improved precipitator performance when Meandu Coal was blended with other coals and to determine the properties of other coals that would improve the precipitator performance. We gathered emission data from the power plant trials, measured particle size, and analyzed the fly ash for chemical composition, and electrical resistivity. We calculated drift velocities that confirm that Meandu fly ash is difficult, but Jeebropilly and Wilke Creek are easier to collect. We attributed the small difference between calculated and measured efficiency to the effect of ash resistivity. For the conditions studied, the difference in efficiencies did not primarily depend on particle size or sulfur concentration, but were related to the concentrations of alkali and alkaline earth metal in the fly ash.

INTRODUCTION

Many Australian Coal are considered difficult to precipitate. This is attributed to the low sulfur concentration of the coals and high quartz content of coal ash. This has been a consideration in purchasing Australian Export Coals for some time. Recently, Australia has begun to impose particulate emission standards on coal-fired power plants. Most of the power plants in Australia use Electrostatic Precipitators (ESP) to collect fly ash. Many Australian Coals are low in sulfur and the ashes are high in quartz. These fly ashes are difficult to collect in ESP's. The Meandu Coal, from the isolated Tarong basis, burned at Tarong Power Station has a fly ash that is particularly difficult to collect using an ESP. Table 1 shows that the Meandu Coal has 0.3 percent sulfur and 27 percent ash. The ash from Meandu Coal has 71 percent SiO_2, 27.5 percent Al_2O_3, 1.9 percent TiO_2, and small amounts of other constituents[1]. Table 2 shows that the Meandu Coal, using water injection, has an emission of 470 mg/Nm^3. However, blending the Meandu coal with Jebroopilly Coal, from the Morton basin near Ipswich or Wilke Creek Coal, from the Saurat Basin near Dalby[1], improved the emissions to around 100 mg/Nm^3. The purpose of this paper is to determine the cause of the improved collection efficiency when Meandu Coal is blended with Wilke Creek or Jebroopilly Coal.

ESP PERFORMANCE

The collection efficiency of an ESP is controlled by the Deutsch Equation[2-4]:

$$\eta = 100 \times [1 - \exp(-w \times SCA)]$$

where η = the collect in percent
w = the drift velocity in m/s
SCA = the specific collection area in m^2/m^3-s

The drift velocity can be estimated by[5]:

$$W = k \times \varepsilon \times \varepsilon_0 \times E^2 \times d_{m50} / (\varepsilon + 2) \times \mu$$

where: $k = 1/7$ = ratio of effective drift velocity to theoretical drift velocity
ε = dielectric constant of the dust
$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m = permittivity of free space
E = electric field strength v/m
d_{m50} = mass mean diameter of particles m
μ = gas viscosity Pa.s

Table 1. Coal Properties[1]

% AD	MEANDU	WILKE CREEK	JEBROOPILLY
H_2O	2.9	8.0	4.1
ASH	26.9	13.0	14.3
VOLATILES	27.5		39,8
% DAF			
C	79.5		81.1
H	5.43		6.38
N	1.45		1.61
S	0.37	0.5	0.70
O(DIFF)	13.3		10.2
% ASH			
SiO_2	71.0		61.9
Al_2O_3	27.5		32.7
Fe_2O_3	0.74		1.58
CaO	0.26	1.75	0.74
MgO	0.11	1.40	0.74
Na_2O	0.03	0.80	1.10
K_2O	0.30	0.40	0.66
TiO_2	1.86		2.13
Mn_3O_4	0.01		0.01
SO_3	0.04	0.60	0.22
P_2O_5	0.02		0.04
BaO	0.02		0.07
SrO	0.02		0.06
ZnO	0.02		0.01

The ability to collect fly ash particles with an ESP depends on[5]: fundamental, mechanical, and operational limitations. In this paper, we investigate the fundamental problems associated with the characteristics of the fly ash and gas. These problems include:

- Particle
  - Resistivity
  - Size distribution
  - Strucrure
  - Density
  - Composition
  - Concentration
  - Agglomeration
- Gas
  - Temperature
  - Moisture
  - Flow

The ESP's at Tarong operate at 140 C, use water injection, and seem to have adequate flow patterns. We therefore concentrated on the properties of the particles that effect ESP collection efficiency.

Particle size did not seem to have a major effect on the collection efficiency for the coals studied. However, the nature of the fly ash particles did. We found resistivity to be the most important fly ash property.

The ESP's at Tarong operate at 20 kv over a 150 mm^3 spacing. This is a low voltage. It is restricted by the breakdown and charging of the gas in the high gradient regions between particles. The potential could be increased if the particle resistivity was reduced.

EXPERIMENTAL

Tarong Power Station provided operating data and samples of the coal and resulting fly ash. The samples were analyzed for particle size distribution, chemical composition, and resistivity. Australian Industrial Coal Research Laboratory (ACIRL) performed the analyses[6].

RESULTS

Table 2. shows the plant measurements for the Trials of Meandu Coal blended with Wilke Creek.

Table 2. Operating Performance of Meandu and Wilke Creek Coals[3,7,8,9]

COAL	100 % MEANDU	50 % WILKE CK	100% WILKE CK
COAL T/H	170	138	138
% ASH	29.7	21.3	12.8
GAS DEN @140	0.88	0.88	0.88
FLUE GAS KG/S	626.2	627.6	689.1
IN DUST g/Nm^3	15.9	9.2	5.0
OUT DUST g/Nm^3	470	107	67
ESP EFF	97.0	98.8	98.8

Table 3. shows estimated efficiencies based on the Deutsch Equation. Baker, et al[6], measured the dieletric constant for Meandu Coal as 1.79 and for Blackwater Coal (similar to Jeebropilly and Wilke Creek Coal) as 7.33. Here, we assume the dieletric constants for Jeebropilly and Wilke Creek Coals are about 10.

Table 3. Calculated Drift Velocities and ESP Efficiencies

COAL	100 % MEANDU	50 % JEEBROPILL	100 % JEEBROPILL	10 % WILKE CREEK
W cm/s	1.48	1.56	1.62	2.02
CAL EFF	97.87	98.27	98.50	99.47

Figure 1. shows that increasing alkali and alkaline earth metal concentration reduces the Meandu and Jeebropilly fly ash resistivity.

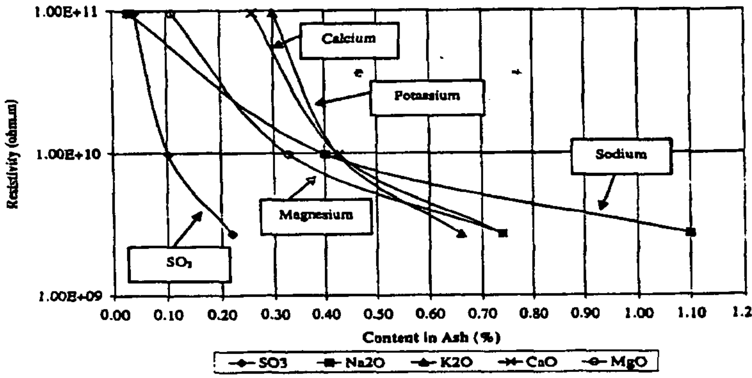

Figure 4.8: Influence of ash properties on resistivity

DISCUSSION

We find that the alkali and alkaline earth metal concentrations are the most important factors reducing the resistivity of the fly ash. This is consistent with earlier findings. Bush and Snyder[10] found that sulfur, alkali metals, and water have the largest influence on fly ash resistivity. Harker and Pimparkar[11] reported that sulfur had limited effect on fly ash resistivity. Bush and Synder[10], Bickelhaupt[12], Tidy[13], and White[14] now believe that the concentration of alkaline metals on the surface of fly ash particles are the most important factor in reducing resistivity.

Bush and Sydner[10] suggest that calcium and magnesium also reduce resistivity. Bickelhaupt[12] argues that potassium and lithium are key components in reducing ash resistivity. Tidy[13] showed that calcium, magnesium, lithium, and potassium were present on the surface of fly ash particles, but were less important in reducing resistivity than sodium. Bickelhaupt[12] thinks the reduced resistivity may be a combination of the above metals.

We find that all the alkali and alkaline earth metal reduce fly ash resistivity. The metals with the smallest ionic radii reduce fly ash resistivity the most for the coals studied. However, lithium concentration was not measured in the current study.

RECOMMENDATIONS

We will measure the lithium concentrations on the fly ash samples. In addition, we will do pilot scale combustion and ESP trials to determine the optimum amount of coal and type of coals to blend and to investigate the effect of injecting solutions of alkali and alkaline earth salts into the duct.

ACKNOWLEGMENTS

The authors would like to acknowledge the help Tarong Power Station gave to this project. They would also like to acknowledge the work that ACIRL, Ipswich, did.

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