

ELECTROSTATIC SEPARATION OF PYRITE FROM COAL

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Abstract: This paper reviews the various forms of electrostatic separation available to remove sulphur, in the form of pyrite (FeS_2) from coal. Research has been carried out to desulphurise coal using an electrostatic roll separator which uses the corona charging technique. Data is presented here to conflict with previous reports that indicated that the electrostatic roll separator is unable to separate pyrite from coal. Separation was undertaken under various atmospheric conditions, with various feed pretreatments.

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INTRODUCTION

Electrostatic separation has several potential key advantages for coal cleaning:

1. The ability to process fine particles ($-45 \mu\text{m}$),
2. High separation/economic efficiency,
3. Environmentally clean: does not use chemical reagents unlike froth flotation,
4. Dry process.

In any physical separation process forces are at work; these forces must be selective and sufficient to effect a separation. Electrostatic forces are generated by the action of an electric field on a charged particle.

Thus, any electrostatic separation needs a source of electrical potential to generate the electric field, and a process to charge the particles electrically. Once the

charging is complete, certain advantages can be seen in electrostatic separation:

- (1) Electrostatic forces work only on the particles to be separated, and do not effect the medium in which the particles are located.
- (2) Trajectories of the particles, influenced by electric field, follow field lines. Thus electric field lines may be shaped for a specific application.
- (3) The direction of electrostatic forces may be reversed by either changing the polarity of the charge, or the direction of the external electrostatic field.
- (4) Electrostatic forces may be arranged to work in combination with other forces, such as gravitational or centrifugal forces.
- (5) Electrostatic forces are independent of the material type on which the charge has been generated, the forces affect all materials to a varying degree. They are determined directly by the product of the electric field and the charge on the particle.

There are two types of electrostatic separation, electrophoresis, which involves charged particles, and dielectrophoresis, which involves uncharged particles.

The main consideration with electrostatic separation using electrophoresis is the charging of the particles to be separated. Every application requires a different system to generate the opposite polarities needed to effect a separation.

There are three main methods of charging:

- (1) Triboelectrification or contact charging
- (2) Corona electrification
- (3) Induction

Triboelectrification charging features particle/particle and/or particle/surface contacts to produce the charge. This is done in various systems, including fluidised beds, cyclones and vibrating beds. Particles are then separated by free falling between two plate electrodes, and are deflected by the electric field set up between

the electrodes. Established technology is used for the generation of the electric field required. An advantage of this type of separator is that smaller forces are needed than would be required to, effectively, lift a mass of particles against gravity. Triboelectric charging techniques are well known, but as yet little used in industry.

Most electrostatic separators in use today are of the "high tension" type, using the corona charging technique. A grounded rotor feeds particles into a field of a charged ionised electrode, which charges the particles by ion bombardment. Conducting particles lose their charge to the grounded rotor and are thrown clear, by centrifugal force. They also come under the influence of an electrostatic field of a non-ionising electrode, which further attracts them away from the rotor. Non-conducting particles remain held to the rotor until the charge slowly dissipates, or they are removed by a brush.

Static field separators, using the induction charging method, differ in that they do not have an ionizing electrode, so that particle charging occurs only from a static field. The grounded surface may be a rotor or a stationary surface, such as a plate or screen. Particle charging is generally less, and thus separation efficiency below that of corona charging.

Dielectrophoresis involves the movement of neutral (uncharged) particles in a non-uniform electric field. Particles that are polarized, by the field, move in the direction of the highest field intensity, while non-polarized particles remain unaffected. Dielectrophoretic forces are generally smaller than electrostatic forces, and their application to the minerals industry is very limited.

Coal generally requires grinding to fine sizes to liberate pyrite. Electrostatic separation can effect a successful dry separation of pyrite from coal in these fine size ranges ($- 45 \mu\text{m}$) with the organic sulphur content of coal remaining unaffected. Thus the use of an expensive physical or chemical wet process, normally required for fine particle separation, is avoided.

The electrostatic roll separator (Fig. 1), a unit which uses the corona charging technique, is reported to give poor reductions of pyrite from coal [1, 2, 3]. The method of triboelectric (or contact) charging is reported [2] to be a much more

efficient technique to effectively remove pyrite from coal. The feed is charged by contact with a target surface and then passed through an electrostatic plate separator.

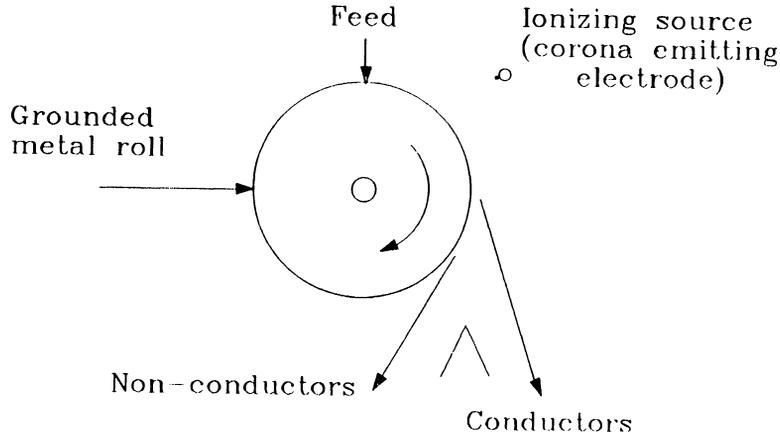


Fig.1 Schematic of electrostatic roll separator

It was decided to substantiate previous reports [1 – 3] that the electrostatic roll separator would be ineffective in separating pyrite from coal. Therefore an electrostatic test programme was undertaken on, primarily, Moira Pottery coal, in various atmospheres, heated feed temperatures and relative humidities, parameters known to affect electrostatic separation [4, 5]. Different atmospheres (e.g. carbon dioxide and nitrogen) were tested to find out if these environments could be used without any detrimental effect on the separation of pyrite from coal. The purpose of the use of different atmospheres being to reduce the explosion risk of treating fine coal dust ($-90 \mu\text{m}$) in the presence of a potential ignition source, i.e. the potential electrical discharge across the electrostatic separator.

EXPERIMENTAL PROGRAMME

The bulk of the test programme was concentrated on three feed size fractions ($-1000+500 \mu\text{m}$, $-500+300 \mu\text{m}$ and $-300+106 \mu\text{m}$) of Moira Pottery coal. The

–106 μm size fraction was not tested due to the explosion risk should the electrostatic separator discharge a spark, i.e. an ignition source. If the tests in different inert atmospheres were a success then tests on the finest size range are to be included in further work.

The first series of experiments were carried out at ambient atmospheric conditions, with no feed heating at 60°C and feed heating at 100°C. Other operating variables, such as roll speed, feed rate, electrostatic potential and splitter plate positions, remained constant so a direct comparison of the results could be made. The electrostatic potential of 20 kV was adhered to where possible. The heated feed tests used a reduced value of electrostatic potential between 10 kV and 15 kV due to apparent agglomeration of the coal particles on the vibratory feeder at higher electrical potentials.

The second set of experiments were undertaken using different environments at low relative humidities (approximately 30%), reported to enhance electrostatic separation results [4, 5]. Atmospheres of nitrogen, carbon dioxide and compressed air were tested. Once again, other separator variables were kept constant. In the case of the nitrogen atmosphere the electrical potential generated by the power unit was substantially reduced, to less than 10 kV. This may be due to the ionising effect of the nitrogen atmosphere.

RESULTS

Tables 1 and 2 illustrate the ultimate and proximate analysis of the Moira Pottery coal used for the electrostatic test programme.

Table 1 Ultimate analysis of Moira Pottery: Seam P20

COAL TYPE	% CARBON	% TOTAL SULPHUR	% NITROGEN	% HYDROGEN	% MOISTURE
MOIRA POTTERY	59.18	3.50	1.06	4.24	2.00

Table 2 Proximate analysis of Moira Pottery coal size fractions (as received basis)

SIZE RANGE microns	% ASH	% TOTAL SULPHUR	% MOISTURE	%VOLATILE MATTER	CALORIFIC VALUE DRY BASIS MJ/kg
1000+500	11.23	3.55	10.43	33.37	24.52
500+300	12.00	3.39	9.59	34.56	24.53
300+106	11.76	3.79	9.98	27.63	24.49

Table 3 shows the ash, total sulphur and calorific value analysis from tests using the electrostatic roll separator on Moira Pottery coal under ambient conditions. Figures 1 and 2 show the ash and total sulphur reduction figures. Ash reductions range from 16.00% to 23.05%. Sulphur reductions range from 10.61% to 15.44% across the size ranges tested.

Table 3 Results of Moira Pottery coal tested on the electrostatic roll separator at ambient conditions (dry basis)

SIZE RANGE	microns	.-1000+500	.-500+300	.-300+106
ELECTRICAL POTENTIAL	kV	20	20	20
FEED	% Ash	12.54	13.27	13.06
	%Total Sulphur	3.96	3.75	4.21
	Cal. Value MJ/kg	27.85	26.82	27.02
NON-CONDUCTORS	% Weight	81.29	74.13	89.78
	% Ash	9.65	10.74	10.97
	%Total Sulphur	3.54	3.31	3.56
	Cal. Value MJ/kg	27.65	28.03	27.95
MIDLINGS	% Ash	21.74	19.23	23.3
	%Total Sulphur	5.84	4.19	4.95
CONDUCTORS	% Weight	4.15	15.69	7.04
	% Ash	25.21	30.79	42.34
	%Total Sulphur	7.13	6.87	10.47

Tables 4 and 5 show the ash, total sulphur and calorific value analysis from tests using the electrostatic roll separator on Moira Pottery coal under ambient atmospheric conditions using heated feed samples, at 60°C and 100°C, respectively. Ash and total sulphur reduction figures are graphically represented in figures 3 and 4. Ash reductions were consistent, a majority being between 10% and 22%. The highest reduction was 32.10%, for the -500+300 μm size range.

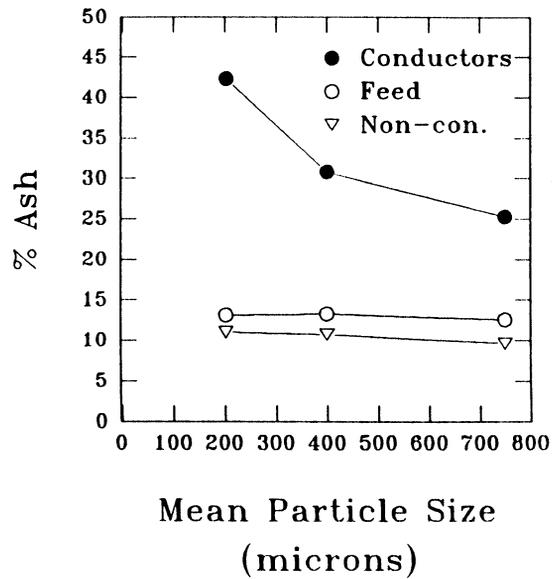


Fig. 1 Moira Pottery coal ash content (dry basis) in electrostatically separated fractions (ambient conditions)

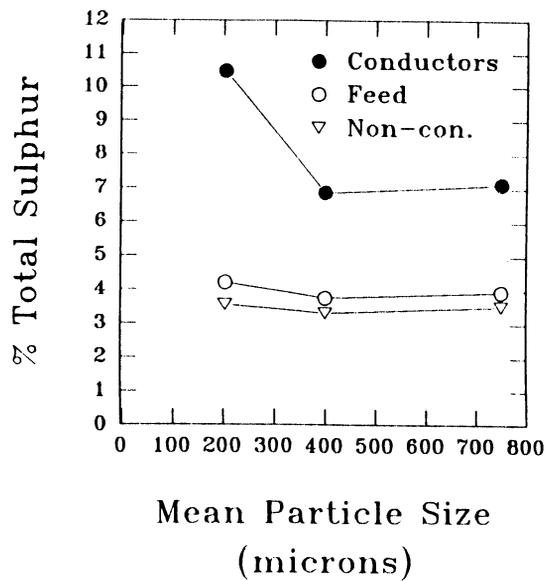


Fig. 2 Moira Pottery coal total sulphur content (dry basis) in electrostatically separated fractions (ambient conditions)

Table 4 Results of Moira Pottery coal tested on the electrostatic roll separator at ambient conditions and feed heating to 60°C (dry basis)

SIZE RANGE	microns	.-1000+500	.-500+300	.-300+106
FEED	% Ash	12.54	13.27	13.06
	%Total Sulphur	3.96	3.75	4.21
	Cal. Value MJ/kg	27.85	26.82	27.02
NON-CONDUCTORS	% Weight	84.81	55.17	94.07
	% Ash	10.96	9.01	11.71
	%Total Sulphur	3.34	3.26	3.67
	Cal. Value MJ/kg	26.89	27.75	26.44
MIDLINGS	% Ash	19.26	10.58	17.62
	%Total Sulphur	5.28	3.13	4.28
CONDUCTORS	% Weight	7.46	32.75	2.89
	% Ash	23.34	23.19	40.22
	%Total Sulphur	7.47	5.06	10.25

Table 5 Results of Moira Pottery coal tested on the electrostatic roll separator at ambient conditions and feed heating to 100°C (dry basis)

SIZE RANGE	microns	.-1000+500	.-500+300	.-300+106
FEED	% Ash	12.54	13.27	13.06
	%Total Sulphur	3.96	3.75	4.21
	Cal. Value MJ/kg	27.85	26.82	27.02
NON-CONDUCTORS	% Weight	89.25	67.2	95.98
	% Ash	10.44	10.46	12.34
	%Total Sulphur	3.31	3.2	3.88
	Cal. Value MJ/kg	26.55	26.11	26.09
MIDLINGS	% Ash	20.17	13.76	22.64
	%Total Sulphur	5.78	3.44	6.41
CONDUCTORS	% Weight	2.99	21.46	1.94
	% Ash	35.15	25.47	39.82
	%Total Sulphur	12.43	6.53	13.68

Sulphur reductions ranged between 13% and 16%, with the exception of the -300+106 μm size range when feed of 100°C was treated. Therefore there appears to be no separation advantage gained from preheating feed prior to electrostatic roll separation. Also problems with agglomerating fines (-300+106 μm) affected the separation efficiency. This is reflected in the inconsistencies which can be seen in Figures 3 and 4.

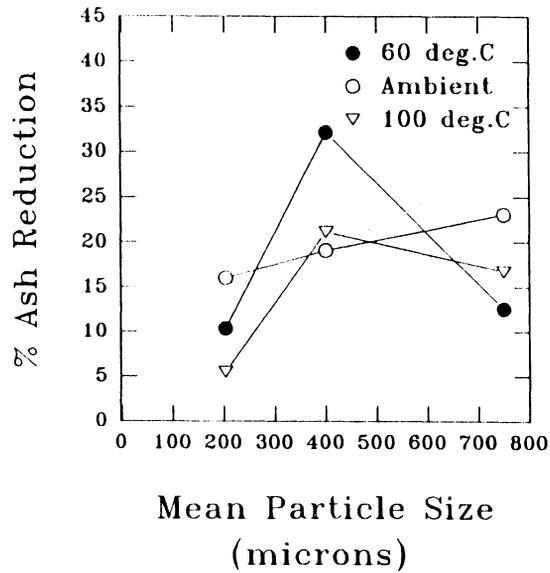


Fig. 3 The effect of pre-heating on ash removal (dry basis) on Moira Pottery coal prior to electrostatic separation

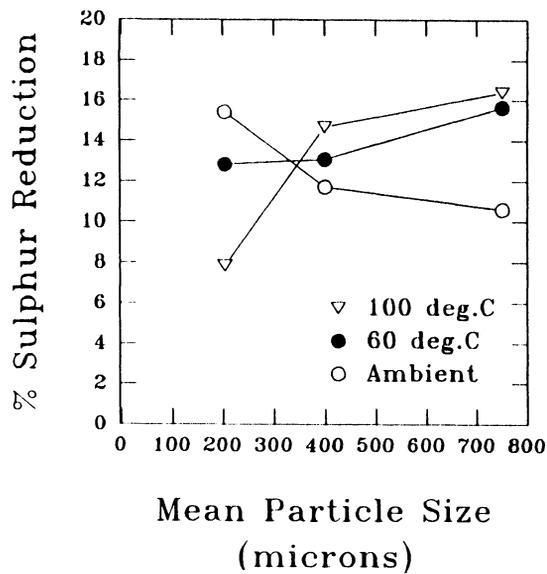


Fig. 4 The effect of pre-heating on sulphur removal (dry basis) on Moira Pottery coal prior to electrostatic separation

Figures 5 and 6 show the ash and total sulphur reduction figures from tests using the electrostatic roll separator on Moira Pottery coal under various atmospheres,

nitrogen, compressed air and carbon dioxide, respectively. The $-500+300 \mu\text{m}$ size range gave considerably better ash reduction results than the other size ranges tested, up 50.64% in compressed air. This is misleading in that the splitter plate positions were optimised more effectively for this size range, a greater proportion of reject being removed than for the other size ranges.

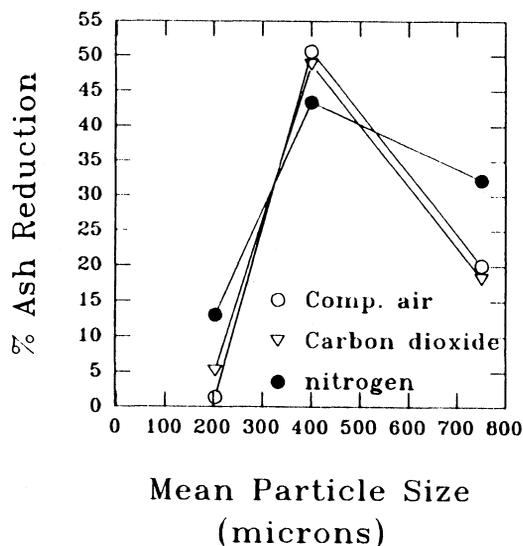


Fig. 5 The effect of atmospheric environment on ash removal from Moira Pottery coal during electrostatic separation (dry basis, R.H. 30%)

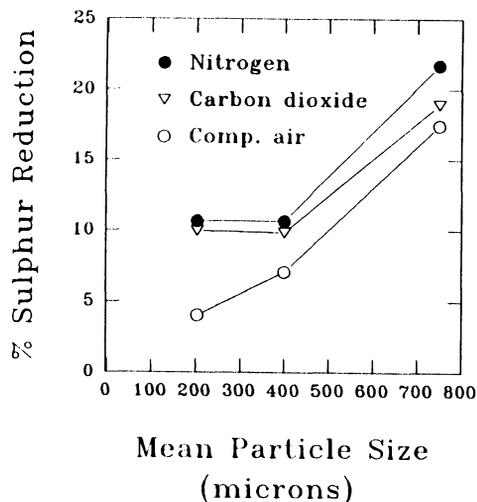


Fig. 6 The effect of atmospheric environment on sulphur removal from Moira Pottery coal during electrostatic separation (dry basis, R.H. 30%)

Thus the results for the $-1000+500 \mu\text{m}$ and $-300+106 \mu\text{m}$ size ranges can be improved if the splitter position is adjusted. The effect of these low reductions figures is reflected in the high concentrations of sulphur in the reject fraction (the conductors), up to 10% in the $-300+106 \mu\text{m}$ size range tested in compressed air. Sulphur reductions ranged from 4.04% to 21.72%, the highest reductions being effected in the $-1000+500 \mu\text{m}$ size range.

CONCLUSIONS

Electrostatic separation of Moira Pottery coal under ambient conditions gave ash reductions between 16.0% and 23.1%, and sulphur reductions between 10.6% and 15.4%, over the size ranges tested. Tests on the treatment of heated Moira Pottery coal feed samples are inconclusive, not showing any apparent overall gain in ash/sulphur reductions over tests at ambient temperature.

Treatment of Moira Pottery coal under different atmospheres (CO_2 , N_2 and compressed air) showed that ash reductions were significantly improved at the low relative humidity (30%) produced when treated in a compressed gas environment. An ash reduction of 50.64% was achieved in a compressed air atmosphere using the $-500+300 \mu\text{m}$ size range, compared to a reduction of 19.07% under ambient conditions on a similar size range.

Both nitrogen and carbon dioxide atmospheres gave results which compare favourably with results achieved under ambient conditions. Therefore it is concluded that both nitrogen and carbon dioxide are an effective inert medium for reducing the explosion risk encountered when processing fine coal ($-90 \mu\text{m}$) in an electrostatic separator. There is, however, a problem using nitrogen, due to the apparent break-down of the electrostatic field created by the corona wire; this may be due to the charging method in use.

Further work will include a test programme to assess the performance of an electrostatic plate separator for the separation of pyrite from coal; previous reports [2, 6, 7] have suggested that this unit is more suitable for desulphurisation than the electrostatic roll separator.

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D.A. Butcher: For biography see *Magn. Electr. Sep.* 4 (1993), 116

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