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POLLUTION CONTROL USING LOW SULPHUR COAL

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ABSTRACT

Acid rain and other factors associated with sulphur oxide (SO_x) emissions are a major problem in many parts of the world today. Operators of coal burning plant are reducing SO_x emission by using low sulphur coal. Australia is fortunate to have low sulphur coals which produce little SO_x when burnt.

Australian utilities have extensive experience with the collection of particulate emissions from power stations burning low sulphur coal. They have been at the front of development on fabric filters and electrostatic precipitators from their first use through to the installation of the most modern computer based technology. Emissions have been controlled by both fabric filters and precipitators.

Where particulate emissions have become excessive as a result of changing to low sulphur coal, economic solutions are now available. This paper discussed the cause of the problem and presents a number of solutions. Using Queensland Electricity Commission data, the effectiveness and cost of emission control solutions are evaluated.

The results demonstrate that SO_x pollution can be reduced without excessive particulate emission by burning low sulphur coal.

INTRODUCTION

Coal users are changing to low sulphur coal in an effort to reduce sulphur oxide gas (SO_x) emissions, a major cause of acid rain. In the USA coal is being transported across the nation to provide east coast utilities with low sulphur coal from the west coast. Low sulphur "west coast" coals contain about 0.5% sulphur compared to over 5% for the high sulphur "east coast" coals.

By reducing the sulphur content of the coal burnt, east coast utilities have achiever better than 90% reduction in SO_x emission without any special control equipment. A further 90% reduction can be obtained using relatively low cost "dry" flue gas SO_x control equipment. Low sulphur coal is the key to dramatically reducing SO_x emissions with a minimum capital outlay.

Australia is extremely fortunate in having a large supply of low sulphur coal containing from 0.2% to 0.6% sulphur. This coal is used in Queensland and New South Wales power stations which have very low sulphur emissions. Sulphur trioxide plus moisture form sulphuric acid, which can cause damage to plants and respiratory problems in humans. Sulphur trioxide emission from Queensland power stations is below 0.01g/Nm^3. This is better than an order of magnitude below the Australian Environment Council recommended limit of 0.2g/Nm^3.

Sulphur dioxide emissions are less of a problem as a photochemical reaction is required to form sulphur trioxide and this will only occur where power stations are built close to highly urbanised areas with appropriate industries. Most power stations in Australia are located well away from the main cities. Even so the sulphur dioxide emissions are also low, with emission levels between 0.4g/Nm^3 and 1.-g/Nm$^{3.}$

Low sulphur coal has a reputation for producing high particulate emissions at stations where electrostatic precipitators are installed. This reputation is not always deserved as there are some Australian low sulphur coals which can be easily collected by precipitators. Even whin problems are encountered, it is possible to modify precipitators at a low cost to allow them to work effectively with difficult coals.

Australian utilities have gained extensive knowledge in the effective collection of ash from low sulphur coal. New developments in technology have been applied on both fabric filters and precipitators at Australian power stations. This experience is available to operators converting their plant to low sulphur coal.

DUST EMISSION CONTROL WITH LOW SULPHUR COAL

Fabric filters were first installed on Tallawarra Power Station in 1972, nine months before their first use on a U.S. power plant. From this start many advances in fabric filter technology have been developed in Australia. The successful use of Acrylic and other new fabrics and application of the High Ratio design are some of the recent developments. Australia’s lead in using the High Ratio design is highlighted by the recent commissioning of the largest installation in the world. The 350MW unit at Munmorah Power Station was a refit into an existing precipitator casing.

Electrostatic precipitators are an older technology which has been studied and refined since the first Australian installation at Bunnerong Power Station in 1938. The applications of advanced computer technology and the use of new energisation technologies are some of the recent developments. Intermittent energisation has been refitted to many existing precipitators and was first installed on new emission control with an acceptable capital cost and a low operating cost, precipitators are used on over 85% of existing installations.

The Queensland Electricity Commission has just contracted to build precipitators for dust emission control at its new Stanwell Power Station. Since this station burns low sulphur Curragh coal, the fly ash collection contract was open to both fabric filters and precipitators. The evaluation of capital and operating costs, based on the data supplied by the manufacturers of the different plant, showed that precipitators were significantly lower in cost.

TABLE I

	High Ratio Fabric Filter	**Low Ratio Fabric Filter**	**Electrostatic Precipitator**
Capital Cost	1.0	1.6	1.25
Capitalised Operating and Maintenance Costs	1.0 (2 yr bag life) 1.0 (3 yr bag life)	N/A N/A	0.2 0.25
Total Cost	1.0 (2 yr bag life) 1.0 (3 yr bag life)	N/A N/A	0.80 0.85

The tender price was lowest for the High Ratio design ($25k/MW), followed by the precipitator ($30k/MW) and the Low Ratio design ($40k/MW). The operating and maintenance costs were much higher for the fabric filters. The total cost, assessed in Table 1, was 20% higher for the High Ratio fabric filter which resulted in the selection of precipitators for Stanwell Power Station. The bag life would need to be extended from two or three years to greater than six years for the total cost to be compatible.

Very few problems have been experienced with collecting ash from low sulphur coal in fabric filters as the dust build-up in bags normally decreases with reducing sulphur content. There has been some experience with dust binding in the bag fabric but this is the exception and can be overcome by using a different fabric. Low sulphur coal should result in lower pressure drop and longer bag life without any increase in emissions.

Precipitators have a reputation for poor dust collection when used to collect ash from low sulphur coal. This is not always true! Blackwater coal, from the Bowen Basin region in Queensland, is used at Gladstone Power Station. This coal is easily collected in precipitators and it has a low sulphur content.

The data presented in Appendix III shows that Blackwater coal has only 0.3% sulphur content and a very high effective migration velocity of 330 millimetres per second. The effective migration velocity, as described in Appendix II, is the best indication of precipitator performance. The effective migration velocity for Blackwater coal ranks its ash as one of the easiest to collect in precipitators, despite the low sulphur content!

Other low sulphur coals such as Callide, West Moreton and Tarong have effective migration velocities about one third that obtained for Blackwater. Why are they so much harder to collect even though the sulphur content is similar or higher? The problem is the ash resistivity! High resistivity ash causes back corona at very low precipitator energisation levels. The many problems caused by back corona are detailed in Appendix II but all result in decreased ash collection and increased dust emission.

Low sulphur coals do not always produce highly resistive ash but those that do can be collected effectively in precipitators! New technology coupled with extensive experience and knowledge of precipitator operation can overcome the problems present by highly resistive dusts. The Queensland Electricity Commission has tested and installed various systems at different power stations and all have improved precipitator operation.

THE COLLECTION OF HIGHLY RESISTIVE ASH IN PRECIPITATORS

By modifying and improving the plant, it is possible to achieve a dramatic improvement in precipitator performance for a low cost. The dust emission from one unit at Swanbank ‘B’ Power Station has been reduced from over 2000 mg/Nm^3. The capital cost of this reproduction was less than $1000 per megawatt of unit capacity.

Reductions of this order may be achieved by implementing improvements aimed at overcoming back corona. Appendix II describes in more detail why back corona is the main cause of high emissions when collecting highly resistive dusts. One method of reducing ash resistivity is the blending of coals. Mixing a coal such as Blackwater, with a more difficult coal, such as Callide, will provide a blend which produces an ash that is easily precipitated.

Precipitator Condition

The reduced performance caused by deterioration in the condition of a precipitator is greatly increased when collecting highly resistive ash. A precipitator which performs well when collecting low resistivity dust may be incapable of collecting highly resistive dust without the rectification of internal problems. Other modifications will be of little benefit until the precipitator condition is improved.

A great deal of expertise, experience and testing is required to pinpoint and rectify faults inside the large “silver box”. Although this box conceals what happens when the precipitator is operating, test data and external measurements will give the experienced investigator clues to the problems within.

Two areas of particular importance are electrode cleaning and corona distribution, since these contribute greatly to the formation of back corona. Corona distribution is affected by:-

Electrode Alignment - The emitter electrode should be equidistant from the collectors.

Emitter Electrode Discontinuities - Any sharp points due to the electrode design, connection system or damage will produce intense corona.

Electrical Connections - Poor connections to individual electrodes will suppress the corona on that electrode and may cause electrode failure due to arcing.

Varying Emitter Dust Thickness - Severe dust build-up on sections of the emitter, caused by back corona, will affect corona distribution.

Energisation System

Traditional energisation control is based on controlling to a set spark rate or maximising average precipitator voltage. This type of control will result in severe back corona causing extremely high emission levels. Highly resistive dusts require energisation levels well below sparling to suppress back corona and produce the best precipitator performance. During acceptance trials at the new Callide ‘B’ Power Station it was found that, by reducing the energisation and suppressing back corona, the emissions could be reduced from over 200 mg/Nm^3.

The “Back Corona Limiting” technique, based on minimum voltage, was developed in Queensland to automatically optimise the energisation of a precipitator collecting highly resistive ash. Its success can be judged by the test results given in Appendix III for Swanbank ‘A’ Power Station. The emissions were reduced from 1500 mg/Nm^3 to 460 mg/Nm^3 simply by replacing the control system which maximised average precipitator voltage with the new system. The benefits are even greater if the original equipment used spark rate control.

First used by Dr White over 20 years ago, intermittent or low-frequency energisation uses an extended ‘off’ period between each burst of charge to suppress back corona. Each charge burst can comprise of one or more ‘on’ cycles at mains frequency using existing SCR and transformer - rectifier units. The main advantages of intermittent energisation is the much higher peak current and more even charge distribution, which can be obtained without causing back corona to form.

Energisation controllers incorporating intermittent energisation were installed on different precipitators by four manufacturers, referred to as Manufacturer ‘A’, and ‘B’, ‘C’ or ‘D’. Details of the precipitator tests are given in Appendix III along with a partial analysis of the dust. The equipment provided by Manufacturer ‘C’ was installed on a Research Cottrell design precipitator, using half wane rectification.

This extensive experience with intermittent energisation has consistently given large reductions in emission and power savings. An emission reduction of about 30% for precipitators with barbed emitter electrodes compared to 60% for straight wires shows the benefits of intermittent energisation is dependent on the electrode design. Coupled with appropriate energisation control, power savings of 15 kW per zone can be achieved. Based on a cost of 10 cents per kilowatt hour, the new energisation controllers would pay for themselves in one year.

Pulse energisation uses bursts of current of a few microseconds duration. Significant improvement has been reported in many pulse installation tests including the tests at Swanbank ‘A’ reported in Appendix III. The main restriction on pulse energisation is the high capital cost. New and more complex transformer-rectifier sets are requires at a cost in excess of A$100,000 per transformer-rectifier unit compared to less than $15,000 for intermittent energisation controllers. This additional cost may be justified on a mew installation, due to the increased potential performance when collecting highly resistive dusts.

Gas Conditioning

The Queensland Electricity Commission has tested many conditioning agents. Steam, currently used at Swanbank ‘B’ Power Station and sulphur trioxide, currently used at Gladstone Power Station, have proven the most successful. If controlled correctly all of the sulphur trioxide injected will be absorbed by the ash and converted to sulphates. Tests at Gladstone have not detected any increased emissions, above the normal 0.01g/Nm^3 when sulphur trioxide infection is used correctly. Its use is limited as it is expensive to install and operate, see Appendix III, and there is potential for atmospheric pollution.

Steam injection has a very high operating cost of over $1 000/Gwh, see Appendix III, but is cheap to install. This makes it suitable where injection is only needed for short periods such as during peak loading or maintenance. Boilers which use continuous drum blowdown to control condensate solids could utilise this waste eater and energy for steam injection. The operating cost for this type of installation would be negligible. Tarong Power Station is evaluation this type of steam conditioning system.

Water conditioning is potentially more effective than steam and has a very low operating cost. It has been used with success but there are dangers. The water must be completely evaporated or the wet dust will cause blockages and corrosion. New technology sonic nozzles will provide the fine water mist required to ensure vaporisation. This increases the capital cost to about $700 per megawatt of unit capacity.

Evaporation of the water reduces the gas temperature and increases the potential for acid corrosion within the precipitator, fan and chimney. The alkaline nature of low sulphur ash will normally absorb any acid collected in the precipitator but additives could be injected with the water if corrosion is a problem. This type of system is used successfully in “dry” flue gas desulphurizers.

CONVERTING TO LOW SULPHUR COAL

Before operating on low sulphur coal, both the coal and the plant should be assessed. Personnel with experience in collecting low sulphur coal ash with a similar type of plant should be involved in this assessment. Without this knowledge and experience to guide the user, converting to low sulphur coal may be an unnecessarily expensive exercise.

A generalised procedure for assessing an installation with existing precipitators is presented. A similar procedure would apply for fabric filters but different aspects of the plant and ash properties would have to be considered.

I. A detailed inspection of the plant with particular attention to electrode condition, effectiveness of electrode cleaning, energisation system and gas flow.

II. Analysis of plant history and proposed future operation to determine the effectiveness and reliability of the plant now and what will be required for the future.

III.Analysis of the present and proposed coal to determine the chemical composition and the ash resistivity. These tests can be performed by both the C.S.I.R.O and A.C.I.R.L. The Australian Coal Industry Research Laboratories can also provide “Knee Point” data which relates to back corona formation conditions. These tests cost from $2,000 for “Knee Point” or resistivity tests to over $10,000 for a complete analysis and evaluation.

IV.If the ash analysis indicates poor precipitation characteristics, it may be wise to perform pilot plant tests. A pilot plant which can also perform burner tests is available at the A.C.I.R.L installation near Brisbane. This plant has both standard and intermittent energisation facilities which can provide valuable data on effective migration velocities and enhancement factors. A pilot plant trial costs between $20,000 to $30,000 depending on the tests required.

V. Based on plant analysis and coal test data the plant performance can be estimated. If improved dust collection is needed this data will provide a basis for the selection of appropriate enhancement systems. After the correction of any internal precipitator problems, a trial burn of at least one week would confirm the performance estimates and allow trial of the selected enhancement system. This type of trial is expensive and should be supervised by experts to ensure the equipment is adjusted correctly and the necessary measurements made.

These five steps will ensure the most economical conversion to low sulphur coal. It is important that each plant and coal be considered separately to ascertain the most appropriate conversion.

CONCLUSION

Low sulphur coal provides a way to greatly reduce the sulphuric acid damage caused by atmospheric emissions of sulphur oxides. The ash from these coals can be collected effectively by fabric filters and electrostatic precipitators. Precipitators have had a reputation for poor collection of low sulphur coal ash but this is not always true. Even those coals with highly resistive ash can be collected using appropriate modern technology.

Before converting to low sulphur coal, tests can be performed to ascertain the plant emissions with the selected coal. If improved dust collection is necessary the most appropriate enhancement technique can be selected. There are many factors which must be considered when converting to low sulphur coal. The most economical solution would require assistance from personnel experienced in the collection of ash from low sulphur coals.

Australian utilities have extensive experience with the collection of low sulphur coal in electrostatic precipitators and fabric filters. The experience and knowledge gained is available to help other users convert to low sulphur coal. Special tests and equipment have been developed in Australian laboratories to assist in the evaluation of ash collection. By utilising this expertise and equipment plant operators can be assured of a cost effective conversion.

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APPENDIX I

FABRIC FILTERS

Fabric Filters can be split into two types, the traditional Low Ratio design and the new High Ratio design. The low Ratio design was developed in the USA where the first full sized filter was not installed on a coal fired power plant until 1973. The first Low Ratio design filter was installed in Australia in 1972. The vast majority of fabric filters installed in the USA and Australia are the Low Ratio design.

High Ratio design filters were first installed on a power station in Australia in 1976. There are only a few installations of this design on power stations in Australia and Europe. Although the High Ratio design has not captured a large share of the market, it is very compact and lower cost. The compact design makes this filter suitable for installation within existing electrostatic precipitator casings as has been done on the 350 MW units at Munmorah Power Station in New South Wales.

The term ratio refers to the ratio of gas volume treated to the area of fabric in the filter. This is effectively the average velocity of gas passing through the filter material.

Both High and Low Ratio filters incorporate hundreds of cylindrical bags grouped in partitioned filter compartments shown in Figure 1. The gas passes from the inside of the bags through the material to the outside on the Low Ratio design and in the opposite direction for the High Ratio design. The open end of each bag is connected to a hole in the tube sheet. This sealed plate prevents the gas from bypassing the bag.

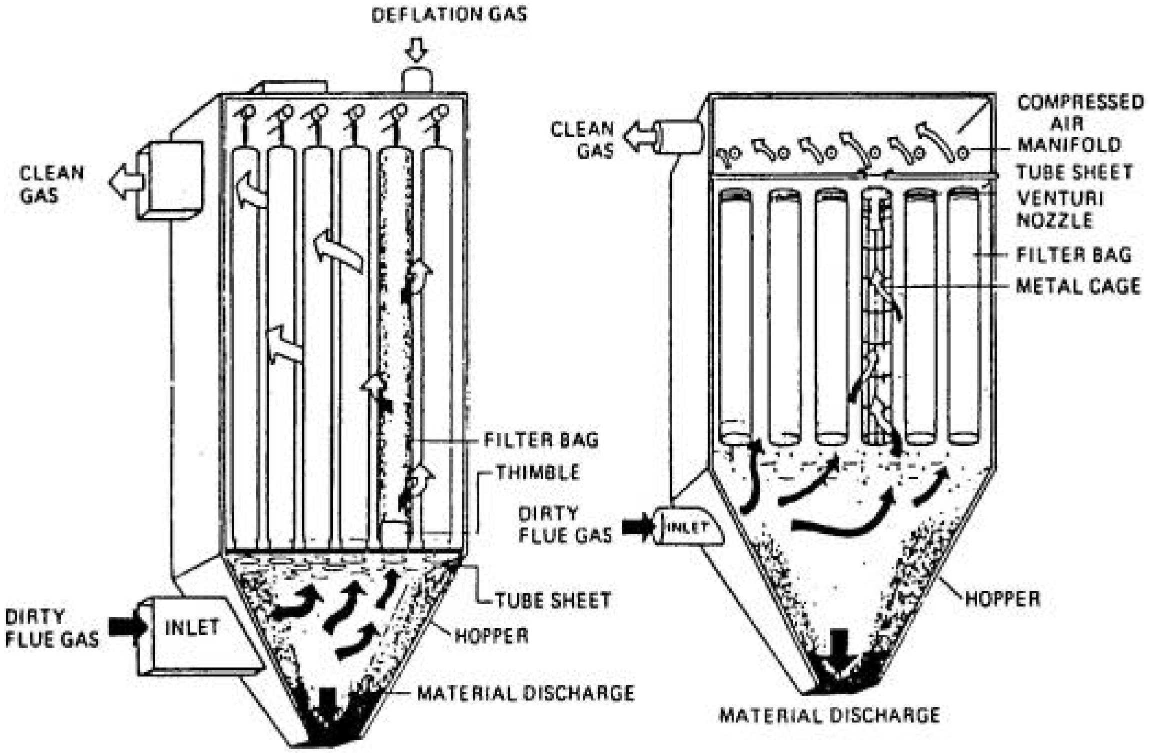

Figure 1(a) Low Ratio Fabric Filter Figure 1(b) High Ratio Fabric Filter

The bags are cleaned using a reverse gas flow. In the Low Ratio design this flow is steady and the cleaning is assisted by mechanically shaking the bags or by sonic vibration induced by high power audio frequency horns. The High Ratio design pulses the reverse gas to give a pressure wave within the bag. This pressure wave expands the bag rapidly and dislodges the dust from the outside of the bag.

Because of the cleaning method the gas must pass from the outside to the inside of the bag in a High Ratio design. Without support the material bag would collapse, so a metal frame is inserted within the bag to hold it open. Table A1 summarises the differences between the Low and High Ratio designs.

TABLE A1

PARAMETER	LOW RATIO	HIGH RATIO
Pressure Drop	1 to 1.5 kPa	1 to 1.5 kPa
Fabric Face Gas Velocity	0.01 to 0.015 m/sec	0.01 to 0.015 m/sec
Gas Flow Direction Through Bag	Inside to Outside	Inside to Outside
Cleaning	Reverse Gas Plus Bag Shake or Sonic Horn	Reverse Gas Pulsed to Flex Bag
Relative Size		About Half Low Ratio
Relative Capital Cost		About 65% of Low Ratio

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PROBLEMS

Fabric filters are not designed for a specific dust emission level, but rather for a specific pressure drop across the filter. Problems with the fabric filter usually show up as a high pressure drop, although bag failure and dust binding in the bag material will cause high emissions.

The main problem areas on an operating fabric filter include:-

I. Dust build up on the bags causing bag failure and increased pressure drop.

II. Dust binding within the bag fabric causing increased emissions and pressure drop.

III. Excessive bag failure causing increased emissions and operating cost.

Early Low Ratio design fabric filters, with reverse gas cleaning only, suffered from inadequate cleaning but the use of sonic horn technology has largely eliminated this problem. Excessive bag failure has occurred on shake clean filters due to poor design of the bag connection and the shaking mechanism. Design changes have overcome these problems resulting in bag life similar to other fabric filter designs.

The main operating cost for a fabric filter is the need to regularly replace bags. The fabric design is the key to the successful operation of a fabric filter. At present the bag life is expected to be three years but this could be extended to five or six years with new materials. This will significantly reduce the high operating cost for fabric filters.

New fabrics, with special coatings to lower dust adhesion, will reduce the potential for dust build up if bag cleaning is inadequate. Membrane coatings can also prevent dust binding within the fabric. It is in the fabric material and weave where most of the filter problems can be alleviated. It will however be a number of years before these materials are tried and tested.

APPENDIX II

ELECTROSTATIC PRECIPITATORS

electrostatic precipitators were successfully used to collect sulphuric acid fume in 1906. Based on this first application by Dr Frederick G. Cottrell, electrostatic precipitator applications quickly expanded into the smelter and cement industries and the technology was well established by 1914.

Electrostatic precipitators are typically constructed of rows of earthed collector plates with rows of electrically energised emitters equidistant from the parallel collector plates. A simplified emitter collector configuration is shown in Figure 1. Virtually all electrostatic precipitators are energised by negative potential, although a similar process does occur with positive energisation.

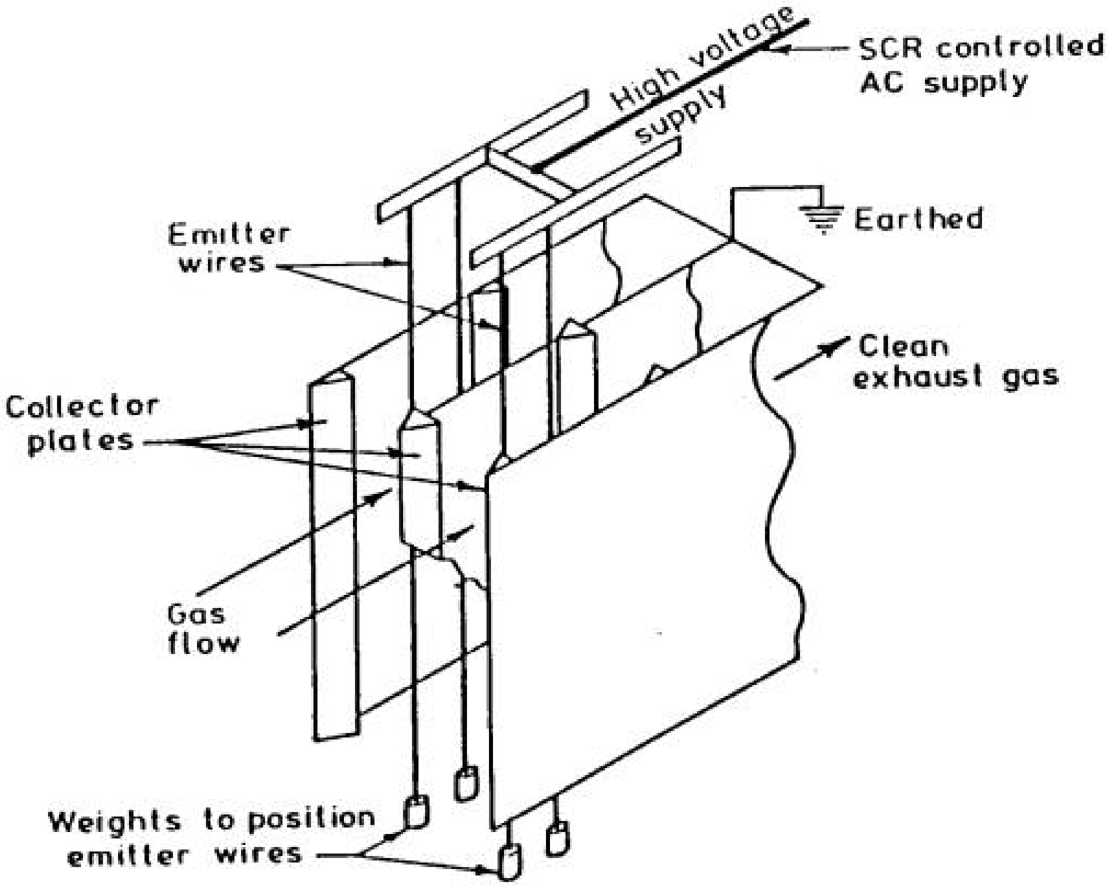

Figure 1 Emitter-Collector Configuration

The electrodes may be of various designs and the emitter electrodes may have sharp po which the corona will form. This corona is the breakdown of gas close to the emitter electrode high electric field induced by the applied negative voltage. Electrons are released by the coron but they quickly form ions which move from the emitter to the collector electrode.

A few of these ions charge the dust particles transported in the gas between the electrodes. The now negatively charged dust particles are forced to move to the collector electrode by the electric field between the electrodes. This results in the dust being removed from the gas to the collector electrode. The rate that the dust is removed can be improved by increasing the applied power, provided sparking or back corona are not present. Both electrodes are cleaned by impact or vibrating which moves the dust down the electrode and removes it in lumps which fall into the hoppers below.

The amount of dust removed from the gas is dependent upon the residence time of the gas between the electrodes. This parameter is termed the Specific Collecting Area (SCA) which is calculated by dividing the total collector plate area by the volume of gas flowing each second. The speed of movement of the dust from the gas to the collector plate also affects the amount of dust collected. This is dependent on the precipitator design and condition as well as the type of dust being collected. Effective Migration Velocity (EMV) is the term given to the average collection velocity of the dust. It is an extremely useful parameter for comparing precipitator performance since it is independent of precipitator size and gas volume treated. The equation which relates these parameters is:-

$$\text{Collection Efficiency} = 1\text{-}e(\text{SCA.EMV})^{0.5}$$

PROBLEMS

There are numerous problems which can cause precipitators to perform will below their potential thereby allowing unnecessary dust emissions. It is very difficult to assess the cause of poor precipitator performance since many of the problems have similar characteristics and may occur coincidently. Considerable experience is required to determine the cause and solution of precipitator problems.

Three problem areas are of particular relevance when collecting highly resistive coal ash.

Back Corona

Back corona is the breakdown of gas at points within the dust layer on the collector electrode. It forms when excessive fields are induces in the dust layer by the charge flowing through a highly resistive dust.

Positive ions, produced by back corona in a negatively energised precipitator, have the following effects:

Ÿ Discharge previously charged dust particles, thereby inhibiting collection.

Ÿ Impact a positive charge to dust particles causing them to move towards the emitter electrode. Dumb-bell or nodule shaped dust build-up on the emitter electrode is an indication of severe back corona.

Ÿ Reduce the space charge density and thereby reduce the rate of particle charging and the emitter corona onset voltage.

Ÿ Discharge the emitter between corona bursts and thereby reduce the field strengths between electrodes.

Ÿ Form sparks at a much lower energisation level.

The level and distribution of the charge on the dust layer and the dust resistance are critical to the formation and continuation of back corona. Poor charge distribution will cause back corona to form at lower currents thereby increasing the susceptibility of the precipitator to back corona.

To control back corona one must control the current. By using the minimum voltage technique to detect the formation of back corona, the back corona onset current can be determined. Cell energisation should be adjusted to control the emitter current to a set value relative to the back corona onset current. This ‘Back Corona Limiting’ energisation control technique ensures that the precipitator runs at the maximum energisation possible without allowing excessive back corona to form, thereby maximising dust collection.

Corona Current Distribution

The corona current distribution at the emitter is controlled by many factors including:

Electrode design

Electrode dust build up

Applied voltage

Electrode electrical connections

Space charge

The corona distribution of barbed electrodes is limited by the barb placement since all corona will form at the sharp points. These electrodes are less susceptible to degradation due to dust build up and low applied voltage but a uniform electrode , whether round, square or star shaped, is capable of better corona distribution than a barbed electrode. The higher the applied voltage the better the corona distribution. A very rapid application of emitter voltage will greatly assist corona distribution and reduce sparking.

Back corona distribution has been shown to cause severe deterioration of the emitter corona.

Deterioration of the corona distribution affects the space charge, thereby reducing particle charging, and the collector current distribution, thereby increasing back corona.

Poor electrical connections to emitter electrodes will result in bad corona distribution and possible failure of electrodes due to arc erosion. The poor corona distribution results from varying connection resistances at each emitter electrode causing each electrode voltage to be different. High resultant voltages between the electrode and the distribution frame may cause electrode failure by arc erosion.

3.) Electrode Cleaning

A good corona distribution is dependent on keeping the emitter electrode distribution is dependent on keeping the emitter electrode reasonably clean. Back corona coupled with a poor electrode cleaning system can result in severe build up. Up to fifty millimetres of dust in the form of balls or sausages has been known to adhere to emitter electrodes.

Back corona is dependent on collector electrode dust build up. The thicker the collector electrode dust layer the more severe the back corona problem for any given dust. To maximise the energy input without causing back corona, the collector dust layer should be no more than a few millimetres.

APPENDIX III

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QUEENSLAND ELECTRICITY COMMISSION
PRECIPITATOR DATA AND TEST RESULTS

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TABLE I Electrostatic Precipitator Emission Tests Results

ENERGISATION CONTROL EQUIPMENT - Coal Type	Opacity %	Outlet Burden mg/m^3 (N)	Collection Efficiency %	Effective Migration Velocity m/s	E.M.V Enchancement Factor	Power kW/Cell
MANUFACTURER ‘A’						
TARONG-TARONG						
Standard (Full Wave)	36	302	99.14	0.095	1.0	15.20
Intermittent	22	194	99.42	0.111	1.17	0.50
GLADSTONE-CALLIDE (SCA = 145 m^2/m^3)						
Standard (Full Wave)	15	257	98.7	0.129	0.1	
Intermittent	12	186	99.1	0.152	1.14	
GLADSTONE-CURRAGH (sca = 101 m2/m3)						
Standard (Full Wave)	19	363	98.0	0.148	1.0	
Intermittent	14	237	98.4	0.168	1.14	
MANUFACTURER ‘B’						
SWANBANK ‘A’ - WEST MORETON						
Standard (Full Wave)	67	1500 (Est.)	92.50	0.055	0.47	17.50
Back Corona Limiting (AV Volts)	46	460	97.70	0.117	1.0	5.26
Back Corona Limiting (Min. Volts)	37	270	98.60	0.153	1.31	1.78
Intermittent	32	180	99.10	0.183	1.56	1.780
Back Corona Limiting(Min. Volts)						
Pulse						
Manual back Corona Limiting (Min. Volts)						

SWANBANK ‘A’ - BLACKWATER Standard (Full Wave)	42	99.7	0.328

TABLE I Electrostatic Precipitator Emission Test Results

ENERGISATION CONTROL EQUIPMENT Power Station - Coal Type	Opacity %	Outlet Burden mg/m^3 (N)	Collection Efficiency %	Effective Migration Velocity m/s	E.M.V. Enchancement Factor	Power kW/Cell
RESEARCH COTTRELL DESIGN						
SWANBANK ‘B’ - WEST MORETON						
Original (Half Wave)	38	1200	94.45	0.112	0.93	
Manual Back Corona Limiting (Min. Volts)						
MANUFACTURER ‘C’						
SWANBANK ‘B’ - WEST MORETON						
Standard (Half Wave)	36	1000	95.50	0.120	1.0	
Back Corona Limiting (Min. Volts)	18	370	98.30	0.177	1.48	
Intermittent						
Back Corona Limiting (Min. Volts)	8	150	99.50	0.264	2.2	
Intermittent + Steam						
Back Corona Limiting (Min. Volts)						
		212	98.81	0.092	1.0	
MANUFACTURER ‘D’		39	99.79	0.18	1.96	
CALLIDE ‘B’ - CALLIDE						
Standard (Full Wave)						
Intermittent						

TABLE II Electrostatic Precipitator Data

	‘D’	‘C’	‘B’	‘A’	‘A’
LOCATION OF INSTALLATION	CALLIDE ‘B’	SWANBANK ‘B’	SWANBANK ‘A’	TARONG	GLADSTONE 5/6
RECTIFIER TYPE	FULL WAVE	HALF WAVE	FULL WAVE	FULL WAVE	FULL WAVE
NO. PASSES	4	2	2	4	2
NO. CELLS	5	4	3	6	3
PLATE AREA (m^3/pass)	27200	7822	6237	37065	18612
DESIGN CAPACITY GAS FLOW (m^3/sec/pass)	140	84	52	142	186
DESIGN SCA (m^2/m^3)	194	94	121	261	100
EMITTER ELECTRODE TYPE	Star Wire	Weighted Wire	Spiral Wire	Barbed Rigid	Barbed Rigid
COLLECTOR ELECTRODE CLEANING	Rotating Hammer Bottom	Magnetic Impulse Top	Rotating Hammer Bottom	Rotating Hammer Bottom	Rotating Hammer Bottom
COLLECTOR ELECTRODE SPACING (mm)	280	229	254	300	300

APPENDIX III Coal Data

	SWANBANK	TARONG	CALLIDE	CURRAGH	BLACKWATER

ASH RESISTIVITY AT 5% MOISTURE (by Mass) AND 130 C (ohm/cm)	4.6 x 10^{12} (1.4 x 10^{12} (at 10% H_2O)	2.2 x 10^{14}	1.3 x 10^{13}	9.0 x 10^{11}	3 x 10^{9}
COAL SULPHUR CONTENT (Ultimate/Ash Free)	0.3	0.6	0.25	0.6	0.3

TABLE IV Gas Conditioning Costs

	APPROXIMATE PLANT COST $A/MW Cap.	APPROXIMATE AGENT COST $A/GWhr	APPROXIMATE PRODUCTION $A/GWhr	APPROXIMATE MAINTENANCE $A/GWhr	TOTAL OPERATING COST $A/GWhr
STEM (1 kg/42 kg of gas)	150	185	900	1	1086
SULPHUR TRIOXIDE (20 ppm)	5000	60	7	3	70