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HOW TO MAXIMISE THE PERFORMANCE OF PRECIPITATORS COLLECTING HIGHLY RESISTIVE DUSTS

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ABSTRACT

The performance of precipitators collecting highly resistive dusts can be destroyed by back corona. To maximise performance, the enemy, back corona, must be detected and defeated by choosing the right weapons and using them effectively. To ensure victory the factors affecting the formation of back corona must be understood.

This paper highlights some important aspects of back corona and includes techniques for detecting and monitoring the severity of back corona. These techniques may be used to determine the need of refitting the energisation system with new weapons, such as intermittent energisation and ‘Back Corona Limiting’ . Four brands of intermittent energisation systems have been used by the Queensland Electricity Commission to defeat back corona. The results of these encounters are used to learn more about controlling back corona.

Gas conditioning, pulse energisation and intermittent energisation are all weapons which have been used against back corona. These weapons are compared to determine the most cost effective method for improving precipitator performance. Implementation of the techniques presented in this paper will defeat back corona, thereby reducing emissions.

1. INTRODUCTION

To maximise the performance of precipitators collecting highly resistive dust, three important axioms should be remembered and applied.

AXIOM NUMBER ONE Know your enemy.

If a precipitator collecting dust with a resistivity above 10^{10} ohm.cms does not perform to normal expectations, back corona is probably the culprit. The susceptibility of the precipitator to the formation of back corona and the severity of the performance degradation can be checked. Before describing how to detect back corona and determine the performance degradation, the effects of back corona on the precipitator should be understood.

AXIOM NUMBER TWO Learn form previous encounters.

Precipitators with intermittent energisation are used by the Queensland Electricity Commission to collect high resistivity fly ash from boilers burning pulverised black coal. Controllers from four manufacturers, installed on four precipitators of different design, were used to collect four different flyashes. The benefits and costs of these new energisation controllers are compared to other techniques used by the Queensland Electricity Commission to improve precipitator performance.

AXIOM NUMBER THREE Choose your weapons well.

If back corona is found to be a problem, there are cost effective ways to improve the precipitator performance. ‘Back Corona Limiting’ prevents the precipitator energisation cycle during which the potential for back corona to form decreases. These weapons against back corona are the latest in an armory which includes gas conditioning, pulse energisation and precipitator design enhancements.

2. THE ENEMY - BACK CORONA

Back corona is a complicated phenomenon which has been the subject of many investigation (1,2,3,4,5,6,7). There are a number of facts regarding back corona which should be emphasised:

(a) Back Corona Destroys Precipitator Performance

Back corona forms at points in the dust on the Collector Electrode causing re-entrainment of previously collected dust. Positive ions, produced by back corona in a negatively energised precipitator, have the following effects:

(i) Discharge previously charged dust particles, thereby inhibiting collection (1).

(ii) Impart a positive charge to dust particles causing them to move towards the Emitter Electrode (1). Dumb-bell or nodule shaped dust build-up on the Emitter Electrode is an indication of severe back corona.

(iii) Reduce the space charge density and thereby reduce the rate of article charging and the emitter corona onset voltage (1).

(iv) Discharge the emitter between corona bursts, thereby reduce the field strengths between electrodes (2).

(v) Form sparks at a much lower energisation level (3,4).

(b) Back Corona is Dependent on Current

Back corona forms when excessive fields are induced in the collected dust layer by the charge flowing from the Emitter Electrode to the surface of the dust layer. The level and distribution of the charge on the dust layer are critical to the formation and continuation of back corona (2). Poor charge distribution will cause back corona to form at lower currents. A precipitator with good corona distribution at the Emitter Electrode can operate at higher currents without back corona.

(c) Back Corona is Self-perpetuating

The current will increase following back corona onset and will tend to be funnelled into existing back corona regions. This will accelerate back corona formation and intensify existing back corona. Factors involved in this process are:

(i) Reduced space charge, in the region of the back corona formation, increases the intensity of the emitter corona charge generation at that point (2).

(ii) Reduced emitter corona onset voltage allows additional charge generation in the region of the back corona.

(iii) Localised field disturbances at the collected dust layer, due to positive ion generation, increase the charge flowing into and feeding the back corona (4,5,6,).

2.1 Finding the Enemy - Back Corona Detection

Voltage/current characteristics are the accepted technique for determining the presence of back corona (3). Traditionally, the average emitter voltage was used but a more accurate indication is obtained by using the minimum voltage (2). Typical voltage and current waveforms are shown in Fig. 1, with a graph of the voltage and current waveforms are shown in Fig. 1, with a graph of the voltage/current characteristic. The minimum voltage is measured to the bottom of the wave while the maximum voltage is measured at the peak of the wave.

By monitoring the current flowing through the dust to the Collector Electrode, it was found that the current peaks increased dramatically when back corona formed (7). The increase in the peak current at the Collector Electrode coincided with a reduction in minimum emitter voltage and precipitator. Back corona causes the minimum following back corona induced phenomena:

(a) Reduced space charge

(b) Decreased emitter corona onset voltage

(c) Discharging of the emitter with positive ions.

The maximum emitter voltage will increase with increasing current. The average emitter voltage will only decrease when the effect of back corona on the minimum voltage is sufficient to counteract the increasing maximum voltage (8). This may be well above back corona onset.

The recommended technique for determining the presence of back corona is to measure the emitter current and minimum voltage at fixed increments of increasing current. A reduction in minimum voltage when the is increased indicates the formation of back corona. A lower back corona onset current means the precipitator is more susceptible to back corona.

Due to the elf-perpetuating characteristics of back corona, once formed it will not cease until the current is reduced well below the initial formation current. This results in hysteresis, which can be seen by plotting the voltage/current curve for increasing and decreasing currents (90. Measuring the minimum voltage while reducing the current will yield erroneous results.

2.2 Damage Assessment - Back Corona Performance Degradation

The estimated precipitator performance, actual precipitator performance and the degradation are plotted against current in Fig. 2. the performance of each zone, measured separately (8), is plotted as Curve A. Calculations based on the emitter voltage were used to estimate the expected precipitator performance given in Curve B (1). Curve C is the performance degradation caused by back corona which is the difference between Curves A and B.

Performance degradation due to back corona has the following characteristics (7):

(a) Zero degradation at currents below that required for back corona formation.

(b) Increasing degradation with increasing current above that required for back corona formation.

(c) The degradation is limited at currents above a saturation level.

In the rear zones the back corona formation current is lower, the rate of degradation is higher and the maximum degradation is greater. These factors can be seen by comparing Fig. 2(a) to Fig. 2(b). The dust acquires most of its charge in the first zone, whereas the rear zones are mainly concerned with the collection of the smaller dust. The charging function performed by the front zone coupled with the smaller dust collected in the rear zones combine to increase the degradation tin the rear zones (7).

A precipitator with a very high back corona susceptibility would have a degradation characteristic similar to Fig. 2(c). Although the actual performance curves are similar, in fig 2(c) it does not have the characteristic trough. This type of precipitator characteristic has been observed in plant collecting extremely high resistivity dust using electrodes with poor charge distribution characteristics.

The shape of the minimum voltage characteristic is similar to the back corona degradation curve, since the voltage decreases with increasing current above back corona onset and then stabilises at a lower level. The decrease in emitter voltage provides an indication of the severity of back corona.

It has been shown that the susceptibility of the precipitator to back corona increases with increasing collector plate dust thickness (8). The formation of back corona at a lower emitter current with increased dust thickness supports a relationship between total collector dust layer resistance and back corona onset current. In practice this would mean that better collector plate cleaning will allow a higher emitter current without back corona forming.

2.3 Damage Control - Back Corona Limiting

The zone energisation must be controlled to ensure there is no performance degradation due to back corona. Back corona formation is dependent upon the precipitator current. 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.

Zone energisation should be adjusted to control the emitter current to 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 on all zones without allowing excessive back corona to form (7,9).

It has been observed that a precipitator controlled in this manner will slowly become less susceptible to back corona (9). this is probably due to the removal of back corona initiated discontinuities in the dust, such as holes and higher bulk density. The performance also improved slightly with time, provided the emitter current automatically increases with increasing back corona onset current.

3. THE LATEST WEAPON - INTERMITTENT ENERGISATION

This “latest weapon” was first used by Dr. White (3) over 20 years ago. Intermittent or low-frequency energisation allows an extended “off” period between each burst of charge (10,11). The collected dust layer will discharge during this “off” period. Before back corona can form, the collected dust must be recharged to form a field sufficient to cause breakdown of the interparticulate gas. This allows a much larger charge burst without causing back corona. Each charge burst can comprise of one or more “on” cycles at mains frequency.

Increasing the emitter corona charge generation requires a higher peak emitter voltage. The higher emitter voltage has the benefit of providing a more even distribution of corona on a uniform emitter electrode (12,14). This benefit is diminished if the emitter electrode has barbs or points which concentrate the corona (12,13).

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. A higher space charge density and electric field within the precipitator, during the emitter corona burst, will significantly improve the performance.

Intermittent energisation may use existing S.C.R. controlled transformer-rectifier units. A microprocessor based controller, which regulates the S.C.R. firing angle, is used to implement intermittent energisation. A microprocessor controller incorporating intermittent energisation and “Back Corona Limiting” could be installed on an existing transformer-rectifier unit for less than A$15,000.

3.1 Previous Encounters - Intermittent Energisation Experience

Energisation controllers incorporating intermittent energisation were installed on different electrostatic precipitators by four manufacturers, referred to as Manufacturer “A”, “B”, “C” or “D”. Details of the precipitators are given in appendix A along with partial analysis of the dust. The equipment provided by Manufacturer “C” was installed on a Research Cottrell design precipitator, using half wave rectification. The other three units were installed on precipitators of the controller manufacturers own design, using full wave rectification. The test results are given in Table 1.

The data for Manufacturers “A” and “D” were obtained from acceptance qualifying test for new installations at Tarong Power Station and at Callide “B” Power Station. All adjustments of controller parameters were made by the manufacturers commissioning personnel. The data for Manufacturer “B” was obtained from a test installation on an existing unit at Swanbank “A” Power Station.

These tests were performed by Queensland Electricity Commission personnel with assistance from the manufacturers personnel. The equipment supplied by Manufacturer “B”, which normally uses average emitter voltage to optimise, was modified to implement the “Back Corona Limiting” technique.

The data for Manufacturer “C” was obtained from a test installation on an existing unit at Swanbank “B” Power Station. These tests were performed by Queensland Electricity Commission personnel with assistance from the precipitator consultant Watson and Associates.

It is evident from these tests that an improvement in performance can be gained by incorporating “Back Corona Limiting” and intermittent energisation. Intermittent energisation also reduces the operating costs by dramatically cutting the precipitator power consumption. A conventional energisation controller designed for use on precipitators collecting highly resistive dust should incorporate intermittent energisation and limit the current to pre vent back corona forming.

The pulse energisation system, tested during the series of tests at Swanbank “A”, produced a further improvement in performance. The pulse equipment and the original Research Cottrell Design controller could not be modified to incorporate the “Back corona Limiting”, however the manual adjustment of the current and voltage limit controls was based on the “Back Corona Limiting” techniques.

3.1.1 Learning from Previous Encounters - Effect of Emitter Electrode Design

The effective dust migration velocity enhancement factor given in Table 1 for precipitators with different Emitter Electrode design but collecting dust produced by coal from the same location show:

(a) An eighty-six percent better enhancement with tar shaped straight wires used by Manufacturer “D” compared to the barbed electrodes used by Manufacturer “A”, both collecting ash from Callide coal.

(b) A thirteen percent better enhancement with the weighted wires in the Research Cottrell precipitator used by Manufacturer “C” compared to the spiral wires used by Manufacturer “B”, both collecting ash from West Moreton coal.

These test results provide evidence on the significance of charge distribution. The barbed emitter electrodes used by Manufacturer “A” will not significantly improve their charge distribution characteristics when intermittent energisation is used. Although the spiral wire emitter electrodes have some potential for an improvement in charge distribution, it is the straight wire which has the greatest potential for improvement with intermittent energisation.

Other investigators have reported the poor corona distribution characteristics of a straight, dust coated wire, due to reduced voltage or in the presence of back corona (14). The elimination of back corona will improve the charge distribution in all cases, but the higher emitter voltages will dramatically improve the straight wire corona distribution. The extreme improvement in performance in the precipitators using straight wire electrodes, obtained using intermittent energisation, is most likely due to the improved corona distribution characteristic.

3.1.2 Learning from Previous Encounters - Intermittent Energisation “Off” Period

One interesting relationship detected in these tests involves the increases in “off” period per “on” cycle used in the intermittent energisation with increasing collector dust layer resistance. the average data for all cells except the front cell is given in Table 2.

The first cell was not included, since it has been found that this cell is less susceptible to back corona and has an optimum performance when operating just above back corona onset (9). This is due to particle charging which occurs mainly in the front cell. The bulk resistivity was measured by the Australian Coal Industry Research Laboratories Ltd. using ash collected from tests at Swanbank Power Station (15).

The relationship between optimum “off” period and the collected dust layer resistance means that the intermittent energisation “off” period should be adjusted regularly. The collected dust resistance will vary with dust layer thickness, temperature, coal composition and gas conditioning. It is particularly important to vary the “off” period when the coal supply changes or gas conditioner is added.

Gas conditioning by injecting steam into the dust and gas mixture prior to the precipitator was used at Swanbank “B” Power Station. This gas conditioning did not reduce the emissions significantly until the “off” period was decreased by a factor of three. This reduced the emission level to forty percent of the original. If gas conditioner is to be used periodically the controller should automatically change the “off” period when conditioning starts or stops.

The use of current control based on “Back Corona Limiting” will reduce the need to adjust the “off” period. The current control will track changes in back corona onset current caused by variations in dust layer resistance. This optimisation of the precipitator current improves the performance and reduces the benefits obtained by adjusting the “off” period. The equipment installed by Manufacturer “C”, incorporating “Back Corona Limiting” on the current control, produced little change in the emission for “off” periods from 250 to 500 milliseconds.

3.1.3 Learning from Previous Encounters - Dust Build-up on Electrodes

Internal inspections at Swanbank “B” Power Station found reduced build-up on the Collector Electrodes of precipitators using intermittent energisation. The dust thickness was less than five millimetres compared to a normal build-up of over twenty millimetres. The Emitter Electrodes remained clean indication an absence of severe back corona. At the same station, other precipitators operating above the back corona onset current have an Emitter Electrode dust thickness varying from a few millimetres to over twenty millimetres.

The thinner Collector Electrode build-up is due to reduced dust adhesion allowing the same cleaning energy to remove more dust. The electrical forces holding the dust onto the Collector Electrode are dramatically reduces by intermittent energisation. This is due to the lower current flowing through the dust layer and the discharge of the dust layer during the “off” period.

Cleaner Emitter Electrodes, due to current control incorporating “Back Corona Limiting”, and cleaner Collector Electrodes, due to intermittent energisation, will ensure maximum performance from the precipitator.

4. CHOOSING THE RIGHT WEAPON - A COMPARISON OF PERFORMANCE ENHANCEMENT TECHNIQUES

The results presented demonstrate the reduction in back corona susceptibility, obtained by using intermittent energisation. Other tests involving intermittent energisation have resulted in a similar level of performance improvement (10,11,16). The new controllers cost approximately A$10,000 per cell but reduce power consumption by up to 15 kW per cell. This would result in a payback period of a few years and a significant reduction in emissions would be achieved.

The Queensland Electricity Commission has had experience with gas conditioning and pulse energisation. Both have shown even better reductions in susceptibility and improvement in precipitator performance. Additional emission reductions can be obtained by using gas conditioning with intermittent or pulse energisation.

4.1 Chemical Warfare - Gas Conditioning

The Queensland Electricity Commission has experience with a number of gas conditioning agents, including steam and sulphur trioxide. Steam injection was tested, in conjunction with "Back Corona Limiting" and intermittent energisation, using the Research Cottrell design precipitators equipped with the controller from Manufacturer "C". An air heater sootblower was used to inject steam at a rate of approximately 1 kg/84 kg of gas. The results of this test are given in Table 1.

During the steam injection tests, the back corona onset current increased, indicating a continued reduction in the resistance of the collector plate dust layer. There was a dramatic improvement in performance when the "off" period was optimised with steam injection. A further small improvement over a number of hours, in line with increasing emitter current, followed the initial rapid change.

Where steam injection is found to be effective, it is of greatest benefit on peak load station operation where conditioning is only required over the load peaks or when the precipitator collection is required over the load peaks or when the precipitator collection is reduced. Steam injection could be used to allow higher generation capacity when a precipitator pass is isolated for maintenance. The low installation cost and the rapid performance improvement, with appropriate controller adjustment, makes steam injection suited to periodic use. The steam cost was estimated on continuous use of high pressure steam and could be reduces by an order of magnitude if low pressure steam was used. Further reductions are possible if the steam is only used during load peaks.

Sulphur trioxide is used on a continuous basis at Gladstone Power Station. The capital cost of sulphur trioxide injection plant is high but the operating cost is lower than team. Table 3 gives a capital and operating cost comparison for steam and sulphur trioxide. The production of sulphur trioxide is a chemical process is best operated at a continuous and steady production rate and is not suited to short term periodic operation.

All conditioning agents require an increase in the energy input to the precipitator to attain the best performance.. By reducing susceptibility to back corona, they allow a large increase in emitter current without back corona forming. Should the conditioning stop, it is essential that the emitter current be reduced to prevent severe back corona occurring . If allowed to continue for an extended period, severe back corona can cause excessive emitter electrode dust build-up, which will greatly reduce the precipitator performance even when conditioning is recommenced. Automatic reduction of current to prevent back corona is essential for periodic conditioning and will prevent precipitator deterioration in the event of a conditioning plant failure.

4.2 Electrical Power - Pulse Energisation

Pulse energisation uses bursts of current of microsecond duration. Significant improvement has been reported in many pulse installation tests (11). During the tests at Swanbank "A" a great improvement in performance was attained with pule energisation, see Table !. The main restriction on pulse energisation, when considering refits, is the high capital cost. New and more complex transformer-rectifier sets are required at a cost in excess of A$100,000 per transformer-rectifier unit. The additional cost may be justified on a new installation, due to the increased potential performance when collecting highly resistive dusts.

4.3 Mechanical Suppression - Electrode Design

Since back corona is a current dependent phenomenon, any design change which increases the inter-electrode field while reducing charge flow will improve performance. It has been shown that a large diameter rod Emitter Electrode can achieve both of these improvements (17,18). With intermittent or pulse energisation to ensure a good emitter corona distribution, large diameter electrodes appear to offer a significant design improvement. It is interesting that some early precipitator designs used this type of electrode.

Research suggests that precipitator performance is better now if a narrow Collector Electrode spacing is used to collect highly resistive dusts (19). The reported increases in current density with time is coincident with decreasing precipitation. Eventually both the current and the performance reach a stable level. The plots of performance degradation against current density are similar to the back corona degradation curves. The results indicate a higher rate of degradation (19), with increasing current above back corona

for varying collector plate spacings. The results presented indicate that wider plate pacing may yield a slightly higher velocity, if an energisation controller incorporating “Back Corona Limiting” was used. At 4 mA/m^2, the lowest current density values plotted, a 430 mm plate spacing produced a normalised effective migration velocity of 1.15 compared to 0.85 for the 230mm spacing. A plot of performance at the back corona onset current would be the best indication of the effect of plate spacing.

5. BATTLE STRATEGIES - A FEW SUGGESTIONS

Investigation of poor performance in an existing precipitator should include the following tests on a precipitator with clean Emitter Electrodes and normal Collector Electrode dust build-up:

(a) The susceptibility of the precipitator to the formation of back corona.

(b) the performance degradation due to back corona.

(c) The Collector Electrode dust build-up.

If the susceptibility to back corona is high, a significant improvement in performance is possible. The following list of performance improvement techniques is generally in order of increasing improvement and cost:

(a) Intermittent energisation with “Back Corona Limiting”.

(b) Steam injection to provide additional performance improvement during peak loads or precipitator maintenance.

(c) Pulse energisation if additional performance, above that possible with intermittent energisation, is required.

(d) Continuous gas conditioning.

When designing a new precipitator to collect highly resistive dusts consideration should be given to using pulse energisation. Conventional transformer-rectifier controllers should incorporate intermittent energisation and automatic limiting of the current to prevent back corona. Intermittent energisation controllers should be set to one “on” cycle and the “off” period should be adjusted to maximise the precipitator performance.

Ares for research include the effects of precipitator design changes, such as wider plate spacing and large diameter emitter electrodes, on the susceptibility to back corona and the performance at the back corona onset current. The effects of dust characteristics, such as particle size and bulk density, on the susceptibility to back corona is another area where study is warranted. There is a relationship between dust layer resistivity and both susceptibility to back corona and optimum intermittent energisation “off” period. Knowledge of the nature of this relationship could improve precipitator deign. Research into the subjects raised has the potential to greatly reduce the emissions from precipitators collecting highly resistive dust.

6. ACKNOWLEDGEMENT

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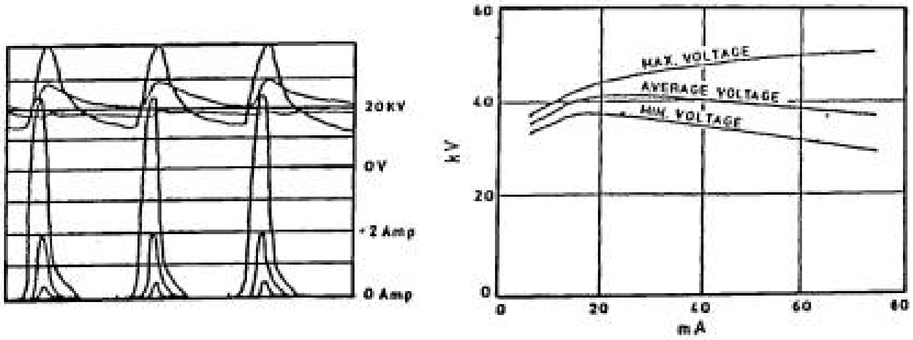
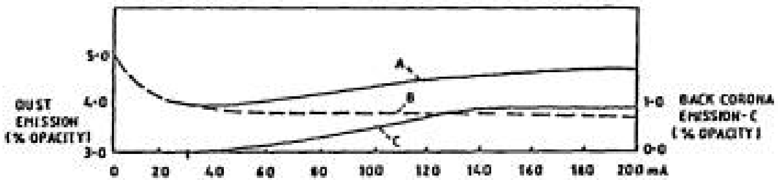
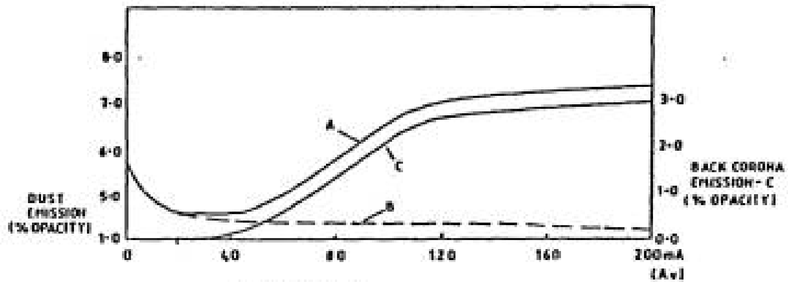


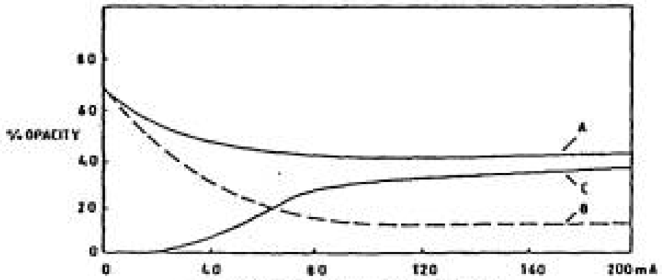
FIGURE 1 EMITTER CURRENT AND VOLTAGE WAVEFORM CHARACTERISTICS FOR SWANBANK 'B' POWER STATION



(a) FRONT CELL



(b) THIRD CELL



(c) HIGH BACK CORONA SUSCEPTIBILITY

CURVE. A ACTUAL CELL PERFORMANCE

CURVE. A ACTUAL CELL PERFORMANCE
CURVE. B ESTIMATED PERFORMANCE WITHOUT BACK CORONA
CURVE. C REDUCTION IN PERFORMANCE DUE TO BACK CORONA

FIGURE 2 BACK CORONA DEGRADATION CURVES

TABLE I. Intermittent Energisation Tests Results

ENERGISATION CONTROL EQUIPMENT -	Opacity %	Outlet Burden mg/m^3 (N)	Collection Efficiency %	Effective Migration Velocity m/s	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 $m^2/m^3/s$)						
Standard (Full Wave)	15	257	98.7	0.129	1.0	
Intermittent	13	186	99.1	0.152	1.18	
GLADSTONE-CURRAGH						
(sca = 101 $m^2/m^3/s$)						
Standard (Full Wave)	19	363	98.0	0.148	1.0	
Intermittent	14	237	98.4	0.168	1.14	
MANUFACTURER 'B'						
SWANBANK 'A'						
Standard (Full Wave)						
Back Corona Limiting (Av Volts)	67	1500 (Est.)	92.50	0.055	0.47	17.50
Back Corona Limiting (Min. Volts)	46	460	97.70	0.117	1.0	5.26
Intermittent						
Back Corona Limiting(Min. Volts)	37	270	98.60	0.153	1.31	1.78
Pulse						
Manual back Corona Limiting (Min. Volts)	32	180	99.10	0.183	1.56	1.780

TABLE 1. Intermittent Energisation Test Results (Cont’)

ENERGISATION CONTROL EQUIPMENT	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)						
Manual Back Corona Limiting (Min. Volts)	38	1200	94.45	0.112	0.93	
MANUFACTURER ‘C’						
SWANBANK ‘B’ - WEST MORETON						
Standard (Half Wave)						
Back Corona Limiting (Min. Volts)	36	1000	95.50	0.120	1.0	
Intermittent						
Back Corona Limiting (Min. Volts)	18	370	98.30	0.177	1.48	
Intermittent + Steam						
Back Corona Limiting (Min. Volts)	8	150	99.50	0.264	2.2	
MANUFACTURER ‘D’						
CALLIDE ‘B’ - CALLIDE						
Standard (Full Wave)		212	98.81	0.092	1.0	
Intermittent		39	99.79	0.18	1.96	

TABLE 2. Intermittent Energisation ‘Off’ Period Analysis

	DUST THICKNESS	DUST RESISTANCE	‘OFF’ PERIOD PER ‘ON’ CYCLE	‘OFF’ PERIOD PER OHM
	cm	ohms	secs	sec/ohm

TARONG	0.1	2.2×10^{13}	1.3	5.9×10^{-14}
SWANBANK ‘A’	0.2	9.2×10^{11}	0.06	6.5×10^{-14}
SWANBANK ‘B’				
No Steam	1.0	4.6×10^{12}	0.31	6.7×10^{-14}
Steam	1.0	1.4×10^{12}	0.1	7.1×10^{-14}
GLADSTONE				
Callide Coal	0.2	2.6×10^{12}	0.13	5.0×10^{-14}
Curragh Coal	0.2	1.8×10^{11}	0.015	8.3×10^{-14}

TABLE 3. Gas Conditioning Costs

	APPROXIMATE PLANT COST $A/MW Cap.	APPROXIMATE AGENT COST 4A/GWhr	APPROXIMATE PRODUCTION 4A/GWhr	APPROXIMATE MAINTENANCE $A/GWhr	TOTAL OPERATING COST $A/GWhr
STEAM (1kg/42kg of gas)	150	185	900	1	1086
SULPHUR TRIOXIDE (20 ppm)	5000	60	7	3	70

APPENDIX A. 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)	300	229	254	300	300

APPENDIX B. Dust Analysis

	SWANBANK	TARONG	CALLIDE	CURRAGH

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}
COAL SULPHUR CONTENT (Ultimate/Ash Free) (%)	0.3	0.6	0.25	0.6
DUST SI02 (%)	58.0	61.0	46.0	57.0
DUST A103 (%)	31.0	35.0	36.0	23.0