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ELECTROSTATIC PRECIPITATOR ENERGISATION FOR THE COLLECTION OF HIGHLY RESISTIVE DUSTS

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ABSTRACT

Back corona or reverse ionisation severely reduces precipitator performance when collecting highly resistive dusts. The best performance will be obtained by designing the precipitator to reduce the susceptibility to the formation of back corona, which must be detected and limited. To achieve these goals 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 for refitting the energisation control with a system incorporating new techniques, such as intermittent energisation and ‘Back Corona Limiting’. Three intermittent energisation systems are evaluated and analysed to determine the best method for adjusting the controller.

Gas conditioning, pulse energisation and intermittent energisation are compared to determine the most cost effective method for improving precipitator performance. Implementation of the techniques presented in this paper will result in a precipitators collecting highly resistive dusts.

I INTRODUCTION

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

If back corona is found to be a problem, there are cost effective ways to reduce the degradation in performance. ‘Back Corona Limiting’ prevents the precipitator energisation from increasing beyond the point where performance degradation commences. Intermittent energisation allows a longer period between each energisation cycle during which the potential for back corona to form decreases. Recently developed energisation controllers may use intermittent energisation to reduce the susceptibility of the precipitator to back corona and ‘Back Corona Limiting’ to prevent performance degradation.

This type of equipment was installed at Queensland Electricity Commission power stations producing high resistivity flyash from boilers using pulverised black coal. Controllers from three manufacturers, installed on three precipitators of different design, were used to collect two different flyashes. Considering these significant variations, the test results presented show a correlation between the dust layer resistance and optimum energisation frequency.

Extensive tests were performed to determine the best methods for adjusting these new controllers and some of the results are presented to highlight significant correlations. The benefits and costs of these new energisation controllers are compared to other techniques used by the Queensland Electricity Commission to improve precipitator performance.

II BACK CORONA

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

a) Back Corona Reduces 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:

- Discharge previously charged dust particles, thereby inhibiting collection (1).
- Impart a positive charge to dust particles causing them to move towards the Emitter Electrode (1). Dumbbell or nodule shaped dust build-up on the Emitter Electrode is an indication of severe back corona.
- Reduce the space charge density and thereby reduce the rate of particle charging and the emitter corona onset voltage (1).
- Discharge the emitter between corona bursts and thereby reduce the field strengths between electrodes (2).
- Form sparks at a much lower energisation level (3,4).

b) Back Corona is a Current Dependent Phenomenon

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 thereby increasing the susceptibility of the precipitator to 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 the back corona formation and intensify existing back corona.

Factors involved in this process are:

  - Reduced space charge, caused by back corona, increases the intensity of the emitter corona charge generation at that point (2).
  - Reduced emitter corona onset voltage allows additional charge generation in the region of the back corona.
  - Localised field disturbances at the collected dust layer, due to positive ion generation, increase the charge feeding into the back corona (4,5,6).

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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 Figure 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.

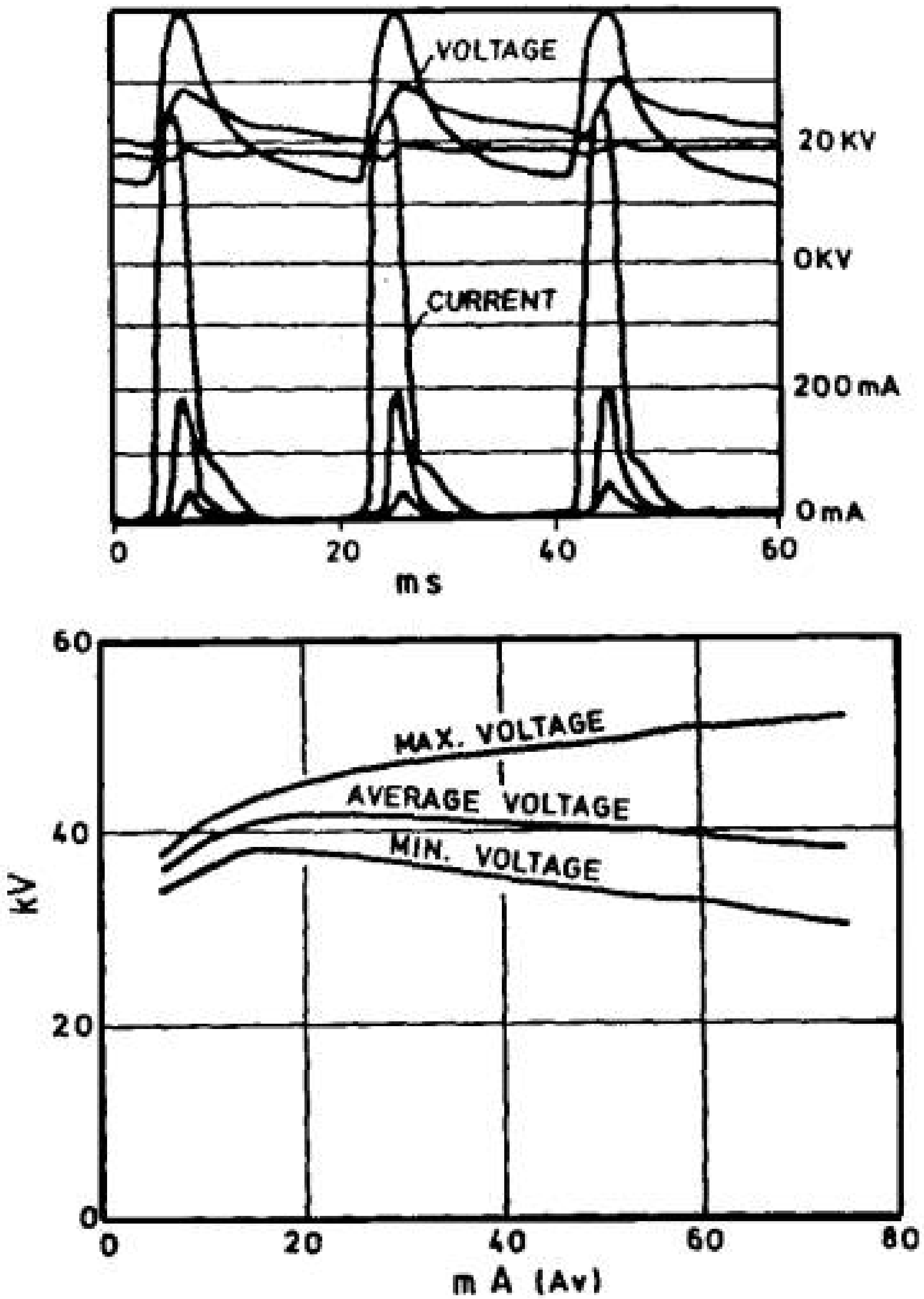


FIGURE 1 - EMITTER CURRENT AND VOLTAGE WAVEFORMS AND CHARACTERISTIC GRAPHS

Upon monitoring the current flowing through the dust to the collector, it was found that the peaks increased dramatically when back corona formed (7). The increase in the peak current at the collector coincided with a reduction in minimum emitter voltage and degradation of precipitator performance. By reducing space charge, decreasing emitter corona onset voltage and discharging the emitter with positive ions, back corona causes the minimum emitter voltage to reduce with increasing current. The maximum emitter voltage will increase with increasing current. The average emitter voltage may decrease, if the effect of back corona on the minimum voltage is sufficient to counteract the increasing maximum voltage (8).

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 current is increased indicates the formation of back corona. This back corona onset current is an indication of the susceptibility of the precipitator to back corona. A lower back corona onset current indicates higher susceptibility.

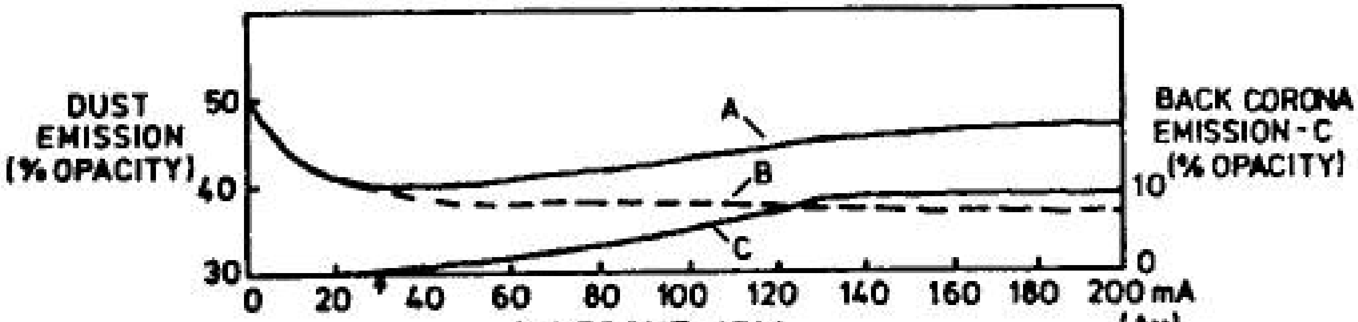
Due to the self-perpetuating characteristics of back corona, once formed it will not cease until the current is reduced well below the initial formation current. This results in hysteresis, which can be seen by plotting the voltage/current curve for increasing and decreasing currents (9). Measuring the minimum voltage while reducing the current will yield erroneous results.

Back Corona Performance Degradation

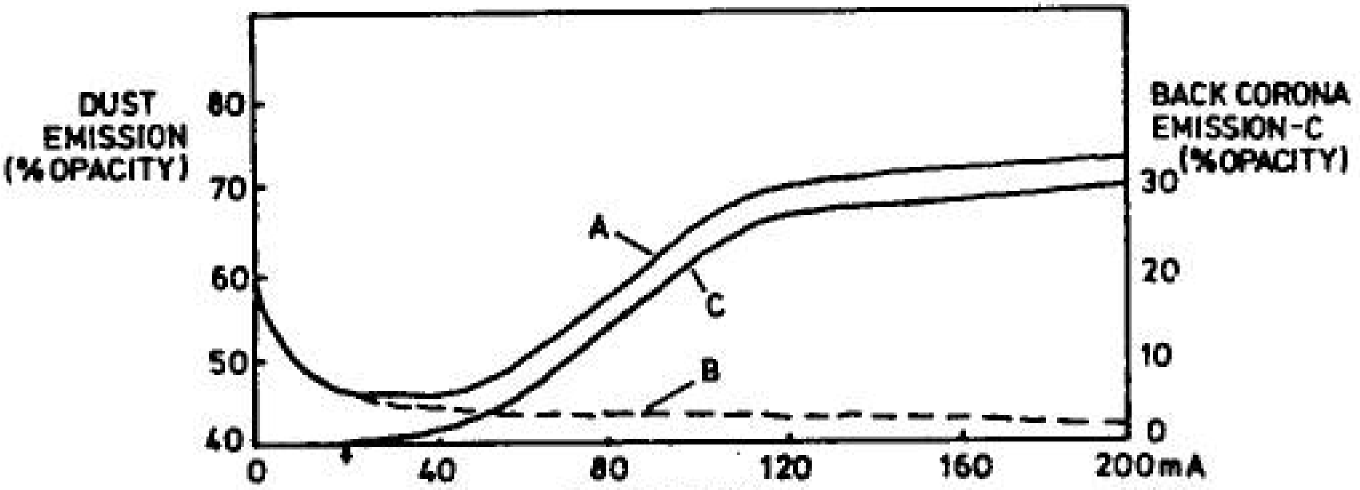
The estimated precipitator performance, actual precipitator performance and the degradation are plotted against current in Figure 2. The performance of each cell, measured separately (8), is plotted as Curve A. Calculations based on the emitter voltage were used to estimate the expected precipitator 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):

- Zero degradation at currents below that required for back corona formation
- Increasing degradation with increasing current above that required for back corona formation.
- The degradation is limited at currents above a saturation level.



(a) FRONT CELL



(b) THIRD CELL

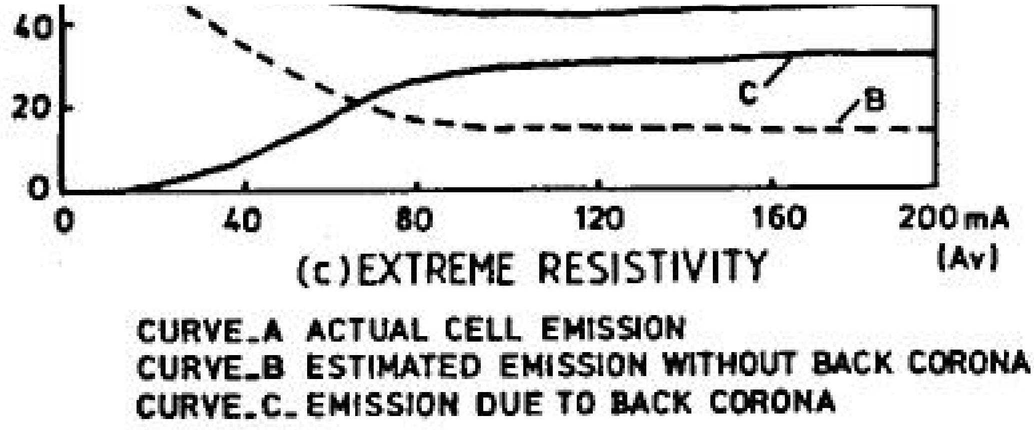


FIGURE 2 - BACK CORONA DEGRADATION CURVES

The back corona formation current is lower, the rate that degradation increases is higher and the maximum degradation is greater on the rear cells. These factors can be seen by comparing Figure 2 (a) to Figure 2 (b). The dust acquires most of its charge in the first cell, whereas the rear cells are mainly concerned with the collection of the smaller dust. These factors result in increased degradation in the rear cells (7).

A precipitator with a very high back corona susceptibility would have a degradation characteristic similar to Figure 2 (c). Although the degradation curve is similar, the precipitator emission curve 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. The voltage decreases with increasing current above back corona onset and then stabilises at a lower level. The decrease in emitter voltage above back corona onset 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 practise this would mean that better collector plate cleaning will allow a higher emitter current without back corona forming.

Back Corona Limiting

The 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.

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 on all electrical sections 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 areas of higher bulk density. The performance also improved slightly with time, provided the emitter current automatically increases with increasing back corona onset current.

III INTERMITTENT ENERGISATION

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 are the much higher peak current and more even charge distribution 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 new controller incorporating intermittent energisation and ‘Back Corona Limiting’ could be installed on an existing transformer-rectifier unit for less than A$10,000.

Intermittent Energisation Experience

Energisation controllers incorporating intermittent energisation were installed on different electrostatic precipitators by three manufactures, referred to as Manufacturer ‘A’, ‘B’ or ‘C’. Details of the precipitators are given in Appendix A along with a 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 two units were installed on precipitators of the controller manufactures own design, using full wave rectification. The test results are given in Table I.

ENERGISATION CONTROL EQUIPMENT	OPACITY %	OUTLET BURDEN mg/m^3 (N)	COLLECTION EFFICIENCY %	EFFECTIVE MIGRATION VELOCITY m/s	POWER CONSUMPTION kW/cell
MANUFACTURER ‘A’					
Standard (Full Wave)	36	302	99.14	0.095	15.20
Intermittent	22	194	99.42	0.111	0.50

MANUFACTURER ‘B’					
Standard (Full Wave)					
Back Corona Limiting (Av Volts)	67	1 500 (Est.)	92.50	0.055	17.50
Back Corona Limiting (Min Volts)	46	460	97.70	0.117	5.26
Intermittent					
Back Corona Limiting (Min Volts)	37	270	98.60	0.153	1.78
Pulse					
Manual Back Corona Limiting (Min Volts)	32	180	99.10	0.183	1.78
RESEARCH COTTRELL DESIGN					
Original (Half Wave)					
Manual Back Corona Limiting (Min Volts)	38	1 200	94.45	0.112	1.90
MANUFACTURER ‘C’					
Standard (Half Wave)					
Back Corona Limiting (Min Volts)	36	1 000	95.50	0.120	1.58
Intermittent					
Back Corona Limiting (Min Volts)	18	370	98.30	0.177	0.73
Intermittent + Steam					
Back Corona Limiting (Min Volts)	8	150	99.50	0.264	3.10

The data for Manufacturer ‘A’ was obtained from acceptance qualifying tests for a new installation at Tarong 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 manufacturer’s 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 prevent 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.

Analysis of Test Results

The test results provide evidence of 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 coasted 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 straight wire Research Cottrell design precipitator is most likely due to the improved corona distribution characteristic.

One interesting relationship detected in these tests involves the increase 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 Table II. 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 at current above back corona onset (9). The bulk resistivity was measured by the Australian Coal Industry Research Laboratories Ltd., using ash collected from tests at Swanbank Power Station (15).

Intermittent Energisation Characteristics

The correlation between the ‘off’ period per ‘on’ cycle and the dust layer resistance was investigate in a series of tests performed with the equipment supplied by Manufacturer ‘C’. This equipment allowed the minimum voltage and peak current to be monitored on each of the two separate emitter frames in each cell. Individually controlled half-waves are used to energise each separate emitter frame and thereby allow additional sectionalisation of the precipitator.

TABLE II

	TARONG	SWANBANK ‘A’	SWANBANK ‘B’

Bulk Resistivity (ohm.cm) at Operating Temperature	2.2 x 10^{14} 130ºC	4.6 x 10^{12} 130ºC	4.6 x 10^{12} 130ºC
Estimated Av Dust Thickness on Collector Electrode (cm)	0.1	0.2	1.0
Approximate Dust Layer Resistance (ohms)	2.2 x 10^{13}	9.2 x 10^{11}	4.6 x 10^{12}
Approximate ‘off’ Period per “on” Cycle (secs)	1.3	0.06	0.31
‘Off’ Period/Ohm of Layer Resistance (sec/ohm)	5.9 x 10^{-14}	6.5 x 10^{-14}	6.7 x 10^{-14}

Manufacturer ‘C’ also incorporated automatic ‘Back Corona Limiting’ as described previously. It was found that the back corona onset current could be up to fifty percent higher on one of the two frames controlled by each unit. This was possibly due to variations in electrode alignment or collector dust layer thickness.

The tests involved:

- Varying the number of ‘on’ cycles.
- Varying the gas moisture content by injecting steam. This caused a variation in dust bulk resistivity.
- Varying the gas temperature and thereby the dust bulk resistivity. This was achieved by changing the cooling air flow through the heat exchanger, prior to the precipitator inlet.
- Varying collector plate dust thickness. This was achieved by eliminating the cleaning for a period of five hours.

Table III presents the results of tests on cells 2 and 3, carried out consecutively over a period of half an hour each. During each test the ‘Back Corona Limiting’ function was used to determine the back corona onset peak current density. Allowing for some variation, due to process fluctuations, an analysis of the results indicate:

- Increasing the number of ‘on’ cycles, with a constant ‘off’ period, results in a reduced back corona onset current density and precipitator performance.
- Increasing the number of ‘on’ cycles, with a constant ‘off’ period per ‘on’ cycle, results in a constant back corona onset current density and a slight decrease in precipitator performance.

The results indicate that the best performance is obtained with one ‘ on’ cycle and the appropriate ‘off’ period. Data from two sets of tests, to determine the best ‘off’ period from the thick dust layer, is also given in Table III. The back corona onset current increases with increasing ‘off’ period but the performance stops improving once peak current per second ‘off’ period stops increasing. This suggests a relationship between average current and performance, when varying the intermittent energisation ‘off’ period.

TABLE III

ON CYCLES	OFF PERIOD		BACK CORONA ONSET CURRENT				OPACITY	
	C2 mS	C3 mS	C2/F1 2 uA/m^2 (peak)	C2/F2 2 uA/m^2 (peak)	C3/F1 2 uA/m^2 (peak)	C3/F2 2 uA/m^2 (peak)	C2 %	C3 %
1	230	310	46.6	41.0	30.2	39.9	21.8	23.0

2	210	330	26.6	26.6	26.7	30.6	22.8	24.0	
3	270	330	25.0	25.7	26.0	28.2	23.0	25.0	
4	230	330	21.0	19.5	27.1	25.6	23.5	24.5	
1	230	310	48.5	38.5	33.2	36.8	22.0	22.5	
Constant ‘off’ period									
1	230	310	46.6	41.0	30.2	39.9	21.8	23.0	
2	450	630	44.4	36.4	32.8	41.4	22.0	23.3	
3	670	930	43.4	41.4	29.7	34.1	22.3	23.5	
4	930	1230	44.0	39.5	35.9	40.4	22.8	22.8	
1	230	310	48.5	38.5	33.2	36.8	22.0	22.5	
Constant ‘off’ period per ‘on’ cycle									

ONSET CURRENT DENSITY/SECOND ‘OFF’ PERIOD									
C1	C2	C1	C2	C1/F1	C1/F2	C2/F1	C2/F2	C1	C2
149	174	190	230	28.2	28.3	40.4	39.6	23.0	22.0
159	178	270	270	45.4	40.5	50.1	45.8	22.0	21.0
135	182	350	310	53.6	41.4	57.7	55.2	22.5	20.0
166	175	270	350	48.0	41.5	62.4	60.3	22.0	21.0
	185		310			58.7	56.2		20.0
Number of ‘on’ cycles = 1									
C1 = cell 1, C2 = cell 2, C3 = cell 3, F1 = emitter frame 1, F2 = emitter frame 2									

An analysis of the data from the three tests involving dust layer resistance is presented in Table IV. The effect of steam and temperature on the bulk resistivity was determined from a set of dust bulk resistance versus temperature graphs for varying moisture content provided by the Australian Coal Industry Research Laboratories Ltd. (15). The increase in dust thickness was estimated using an inlet burden of 20 gms/m^3, a collection efficiency of 90 percent for the first two cells and a loss of 40 percent, due to gravitational fallout combined with sparking.

The front and the second cell data, for the dust layer variation test, shows the lower optimum ‘off’ period per ohm of dust layer resistance due to particle charging in the front cell. The results of these three tests support the previous conclusion, that the optimum ‘off’ period is dependant on the total dust layer resistance.

IV 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 $A10 000 per cell but reduce power consumption by up to 15kW per cell. This would result in a pay back 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.

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 an approximate rate of 1kg/84kg of gas. The results of this test are given in Table I.

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, see Table IV. A small improvement over a number of hours, in line with increasing emitter current, followed the initial rapid change.

TABLE IV

	FRONT ZONE NOT INCLUDED			FRONT & SECOND ZONE ONLY	
	NORMAL 130c 5% H_2O	STEAM 130c 10% H_2O	HIGH TEMP 150C	THIN LAYER	THICK LAYER
Bulk Resistivity (ohm.cm)	4.6×10^{12}	1.4×10^{12}	3.4×10^{12}	4.6×10^{12}	4.6×10^{12}
Estimated Dust Thickness (cms)	1.0	1.0	1.0	1.0	1.6
Approx. Dust Layer Resistance (ohms)	4.6×10^{12}	1.4×10^{12}	3.4×10^{12}	4.6×10^{12}	7.3×10^{12}
‘Off’ Period per Cycle (Sec)	0.31	0.11	0.21	0.21	0.29
‘Off’ Period/Ohm Resistance (sec/ohm)	6.7×10^{14}	7.9×10^{14}	6.2×10^{14}	4.6×10^{14}	4.0×10^{14}

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 reduced. Steam injection could be used to allow higher generation capacity when a 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 reduced by an order of magnitude if low pressure steam was used. Further reductions are possible if 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 steam. Table V gives a capital and operating cost comparison for steam and sulphur trioxide. The production of sulphur trioxide is a chemical process which requires a long start up and shut down time. The process is best operated at a continuous and steady production rate and is not suited to short term periodic operation.

TABLE V

	APPROXIMATE PLANT COST $A/MW Cap.	APPROXIMATE AGENT COST $A/GWhr	APPROXIMATE PRODUCTION $A/GWhr	APPROXIMATE MAINTENANCE $A/GWhr	TOTAL COST $A/GWhr
Steam (1kg/42kg of gas)	150	185	900	1	1,086
Sulphur Trioxide (20 PPM)	5,000	60	7	3	70

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 plan failure.

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 pulse energisation, see Table I. 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 $A100,000 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.

V CONCLUSION

When considering an existing precipitator installation with poor performance, the following aspects should be examined on a precipitator with clean emitter electrodes and normal collector plate dust build-up:

- The performance degradation due to back corona.
- The collector plate dust build-up

- The performance attained at back corona onset current for different boiler loads.

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 to increasing improvement and cost:

- Intermittent energisation with ‘Back Corona Limiting’.
- Steam injection to provide additional performance improvement during peak loads or precipitator maintenance.
- Improved collector cleaning if build-up is excessive.
- Pulse energisation if additional performance, above that possible with intermittent energisation, is required.
- 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 average back corona onset current. The results presented in this paper indicate that this technique will yield controller setting consistent with minimum emission levels.

Areas for research include the effects of precipitator design changes, such as wide 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 susceptivity 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 design. Research into the subjects raised has the potential to greatly reduce the emissions from precipitators collecting highly resistive dusts.

APPENDIX A

PRECIPITATOR DATA

ENERGISATION CONTROL MANUFACTURER	MANUFACTURER 'C'	MANUFACTURER 'B'	MANUFACTURER 'A'
LOCATION OF INSTALLATION	Swanbank 'B' Power Station	Swanbank 'A' Power Station	Tarong Power Station
RECTIFIER TYPE	Half Wave	Full Wave	Full Wave
NO PASSES	2	2	4
NO CELLS	4	3	6
PLATE AREA (m^2/pass)	7822	6237	37065
DESIGN CAPACITY GAS FLOW (m^3/sec/pass)	84	52	142
SCA (m^3/m^2/pass)	94	121	261
EMITTER ELECTRODE TYPE	Weighted Wire	Spiral Wire	Barbed Wire
COLLECTOR ELECTRODE SPACING (mm)	229	254	300
COLLECTOR ELECTRODE CLEANING	Magnetic Impulse Gravity Impact Vertical Top	Rotating Hammers Horizontal/Bottom	Rot. Hammers Horizontal/Bottom

DUST ANALYSIS

	SWANBANK	TARONG
Resistivity at 5% moisture (by mass) and 130ºC (ohm/cm)	4.6×10^{12}	2.2×10^{14}
Coal Sulphur Content (Ultimate/Ash Free) (%)	0.3	0.6
Dust Si02 (%)	58.0	61.0
Dust A103 (%)	31.0	35.0

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