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NEW TECHNOLOGY IMPROVES ELECTROSTATIC PRECIPITATOR PERFORMANCE

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ABSTRACT: Legislative requirements for reducing dust emissions from industrial processes, such as Smelters, Refineries, Kilns and Boilers, have resulted in significant capital costs. Many of these processes use Electrostatic Precipitators to control the dust emissions to the environment. Operating problems can cause reduced electrostatic precipitators performance resulting in high dust emissions. Baltec Systems has developed a range of technologies which can be selected, depending upon the application, to minimize the effect of operational problems and to improve the performance to meet reduced emission requirements. These technologies include gas conditioning using SO_3 or humidification, inlet burden control using mechanical pre-collectors, mechanical enhancements to improve gas flow and cleaning, and enhanced electrical systems using the latest technology in energisation systems and high performance electrodes.

1.0 INTRODUCTION

Electrostatic precipitators are used to remove dust from the exhaust gasses of many processing industries such as power generation, cement manufacture and metal refining or smelting. The effectiveness of the dust removal depends upon operating conditions such as dust size, concentration, composition and distribution plus gas composition, temperature, volume and flow distribution. Changes to the process will affect these conditions and may reduce dust collection. It is also possible to change the operating conditions so dust collection is increased.

Three of the key factors which affect the dust collection efficiency of an electrostatic precipitator are:

Residence Time - The time available to collect a dust particle.

Energisation - The electrical energy available to collect the dust.

Electrode Cleaning - The effectiveness of dust removal from electrodes inside the electrostatic precipitator.

The **Residence Time** is reduced by a range of operating conditions including:

Increased gas volume - This is affected by increased gas temperature or the addition of air or water to cool the gas.

Increased sneakage - This is affected by the amount of gas which bypasses the electrodes, generally by flowing above or below them.

Poor gas distribution - This is affected by gas flow variation, particularly across the inlet of an electrostatic precipitator.

The **Energisation** is limited by a number of operating conditions including:

Sparking - This limits the peak voltage and is affected by electrode clearance, dust concentration, gas temperature and composition. The electrical energy consumption is increased but the dust collection is reduced since the energy is wasted in forming an arc and the power must be turned off to quench this arc.

Back Corona - This limits the average current and is affected by the dust resistivity and gas composition. Again the energy consumption increases concurrent with large increases in dust emissions due to the production of opposite polarity ions which prevent dust collection.

Equipment capacity - This limits the peak voltage and the average current and is mainly affected by the transformer-rectifier rating.

The **Electrode Cleaning** affects both the rate of dust removal and the re-entrainment of the collected dust back into the gas stream, both of which are dependent on operating conditions including:

Dust concentration - This is the factor which determines the rate of dust build-up on the collecting electrodes.

Cleaning interval - This determines the thickness that the dust is allowed to build-up on the electrodes.

Cleaning energy - This determines the amount of dust removed and the percentage reentrained back into the gas stream.

The performance of the precipitator is improved and dust emissions are reduced by:

- Increasing the Residence Time of the dust particles which are not being collected.
- Increasing the Energisation without causing Sparking or Back Corona.
- Minimizing the reentrainment of collected dust while maintaining the optimum Electrode Cleaning.

Operating conditions which reduce precipitator performance can be overcome by using appropriate technology to minimize the effects and enhance dust collection. It is also possible to save energy, thereby reducing pollution and costs with little increase in dust emissions, by optimizing the electrostatic precipitator energisation. This paper initially identifies common operating problems encountered on existing precipitators and their solutions. This is followed by an analysis of performance enhancements made possible by new technology.

2.0 OPERATING PROBLEMS

Some of the most common operating problems encountered by Baltec Systems personnel on a wide range of operating plant are outlined along with the detrimental effects they cause and the methods for diagnosing the problem. Solutions, which normally give the best results in the presence of these operating faults, are also outlined.

The problems which are dust dependent include high inlet dust load, high dust resistivity, emitter electrode build-up and high dust reentrainment. Problems which are plant dependent include high dust reentrainment, poor gas distribution and reduced electrical clearance.

One of the key tools used to diagnose problems is the electrostatic precipitators electrical characteristic. This characteristic is obtained by plotting the electrostatic precipitators voltage against the current. Appendix A details the normal electrostatic precipitators electrical characteristics and the changes which are caused by operating problems.

2.1 High Inlet Dust Load

This is evidenced by reduced power in the front electrical zones of the electrostatic precipitator due to spark limiting or excessive sparking depending on the way the energisation controller operates (see Appendix A). It can result in high power consumption due to sparking and will cause increased dust emissions. Solutions to this problem which Baltec Systems have used include:

Mechanical precollector - A multicyclone or other mechanical dust collector is used to reduce the inlet dust load.

Energisation control - Using the Baltec Systems Optipower ® energisation control unit the type of energisation can be changed during high dust load periods if the condition is process dependent and hence periodic e.g. Blast Furnace.

2.2 High Dust Resistivity

This is a common problem evidenced by increased current at reduced voltage (see Appendix A), and dust build-up on the emitter electrode (see 2.3 Emitter Electrode Build-up). This process problem can be caused by process changes which increase the gas temperature or reduce the steam content. Process variations of this nature are common, for example in dry cement manufacturing or alumina refining. High dust resistivity causes a phenomena called Back Corona which inhibits dust collection even though the current increases (see Ref 1). This will result in high dust emissions in conjunction with high power consumption. Solutions to this common problem include:

SO_3 conditioning - Providing the dust composition is suitable, injecting SO_3 into the gas before the electrostatic precipitators will reduce the dust resistivity and prevent Back Corona.

Humidification - Using a special atomizing nozzle to inject ultrafine water droplets into the gas before the electrostatic precipitators will reduce the gas temperature and increase the steam content of the gas. Both of these factors will act to reduce the dust resistivity and prevent Back Corona. This solution requires a suitable injection point to ensure all of the water is evaporated before entering the electrostatic precipitators.

Energisation control - The Baltec Systems Optipower ® energisation controller automatically detects the presence of Back Corona then alters the energisation to prevent Back Corona and maximize dust collection for the current level of dust resistivity. This technology uses a microcomputer to implement patented Back Corona detection and Form Factor control algorithms which provide optimum electrostatic precipitators performance under varying dust resistivity conditions.

2.3 Emitter Electrode Dust Build-up

This is evidenced by increased voltage and reduced current with increased sparking on the affected electrostatic precipitators zones (see Appendix A). This operating problem can be caused by Back Corona, poor electrode cleaning or wet sticky dust conditions, such as may occur during plant start-up. This can result in reduced power consumption, due to Corona Suppression, and high dust emissions. The solutions to this problem depend upon the cause:

Back Corona - Proper energisation control will ensure Back Corona does not occur and hence emitter electrode build-up will be prevented (see 2.2 High Dust Resistivity).

Poor emitter electrode cleaning - An enhanced electrode cleaning system can eliminate most of the detrimental factors including:

- Infrequent cleaning interval.
- Inadequate cleaning energy.
- Loose electrodes or connections.

Wet Sticky Dust - Pretreatment of the gas before it enters the electrostatic precipitators to ensure appropriate conditions using mechanical pre-treatment and proper energisation control will minimize this condition. Once this condition occurs it is generally not possible to clean the dust off the electrodes without off-line washing.

2.4 High Dust Re-entrainment

This is another common problem which is evidenced by very high emissions during collector electrode cleaning, thus the emissions drop significantly when the electrode cleaning is turned off. This operating problem can be caused by dust characteristics such as low density, low resistivity and poor agglomeration properties or by the collector electrode cleaning problems such as too high a cleaning rate, excessive energy or high electrode movement. The solution to this problem depends upon the cause:

Dust characteristics - Increasing the dust agglomeration will minimize re-entrainment by increasing the size of the agglomerated particles which also makes any that are re-entrained easier to collect. This can be achieved using ammonia injection into the gas stream before the electrostatic precipitator.

Poor collector electrode cleaning - Baltec Systems has developed an enhanced cleaning control system which operates in conjunction with the Optipower ® energisation control to ensure good electrode cleaning with minimum re-entrainment. The mechanical design and condition of the cleaning system is also important. Excessive energy or low frequency, high amplitude electrode vibrations can cause a high component of the dust removed to break up and re-entrain into the gas stream. This can be alleviated by minor modifications to the cleaning system.

2.5 Reduced Electrical Clearance

The most common operating problem, it is evidenced by sparking at reduced voltage (see Appendix A). It can result in high power consumption, due to excessive sparking, but in fact greatly reduces the electrical energy available to collect dust, resulting in high dust emissions. The solution to this problem is simple, remove the cause. The difficult part is identifying the cause and the best method for its elimination. Some common causes are:

Broken or loose emitter electrode - Remove the problem electrode.

Misaligned or bowed collector electrode - Adjust the electrode system and ensure adequate clearance for expansion.

Earthed fitting clearance - The electrostatic precipitators housing and fittings are all properly earthed for safety reasons so any point of reduced clearance will limit the electrostatic precipitators performance.

3.0 PERFORMANCE ENHANCEMENTS

The emissions from precipitators with perfect operating conditions can be reduced and operating costs lowered through the application of technology which was not available when the plant was built. Many of these new innovations can be retrofitted to existing plant with a minimal rebuild which requires only a short shutdown. Four enhancement technologies which Baltec Systems uses are skewed gas, electrical form factor control, energy coordination and electric wind enhanced electrode. These technologies are incorporated into the range Baltec Systems equipment which can be used separately or combined to reduce dust emissions and/or power consumption.

3.1 Skewed Gas

This technology is based on three facts:

- Most of the dust is collected in the front section of the electrostatic precipitator.
- Most of the dust emissions exit from the lower part of the precipitator.
- Dust collection is dependent upon residence time.

The flow distribution at the front and rear of the electrostatic precipitator is adjusted so that it is even across the electrostatic precipitators but increases from the top to the bottom at the front and decreases from top to bottom at the rear. This change will increase the residence time of the dust which would have escaped from the lower part of the electrostatic precipitator and reduce the dust re-entrainment. Both of these factors contribute to increased dust collection which will reduce dust emissions by 30% to 60%.

The key to the successful implementation of this patented technology is the analysis and proper design of the front and rear gas flow distributor. Baltec Systems is the Australian licensee for Stothert of Canada who hold the patents for this technology and are the leading experts on its implementation (see Ref 2).

3.2 Electrical Form Factor Control

This technology is based on the following facts:

- Sparks will occur when the peak voltage exceeds the sparkover limit.
- Back Corona will occur when the time weighted average current flow exceeds the Back Corona onset limit.
- In the absence of sparks or Back Corona, dust collection increases with increased electrical energy supplied to the electrostatic precipitator.

The Voltage Ripple Factor (VRF) is the peak voltage divided by the minimum voltage and will reduce to one with a smooth DC supply. In the absence of any Back Corona, the maximum dust collection will occur with a DC supply having a voltage just below that required for sparkover. Dust with a resistivity of less than 10^6 ohm.cms will be collected at maximum efficiency using a three phase power supply with a very low VRF.

The Current Form Factor (CFF) is a time dependent measurement of the current waveform according to the following equation -

$$CFF=(1/T \quad I^2dt)^{0.5}/I_{mean}$$

where T > 10 . Current Pulse Period

This parameter will also reduce to one with a smooth DC supply. The CFF required to give maximum dust collection will increase with increasing dust resisitivity. Normal single phase energisation will provide maximum dust collection for dusts with resistivities from 10^7 to 10^{10} ohm.cms and intermittent or pulse energisation should be used to maximize dust collection with higher resisitivity dusts.

With low resistivity dusts, the energy consumption can be reduced by more than 60% with only 5% to 10% increase in emissions by increasing the CFF. This small increase in particulate emission will allow a significant reduction in greenhouse gas emissions and an energy saving.

New energy control software incorporated in the Optipower ® optimizes the CFF for each electrical zone in the electrostatic precipitator. The advent of high power Insulated Gate Bipolar Transistors (IGBT) has allowed the precipitator energisation to be turned ON and OFF within microseconds. This enables the Optipower ® to control CFF and provide protection for the electrostatic precipitator power supply.

3.3 Environmental Coordination

This technology coordinates the energisation and cleaning of all electrostatic precipitators zones to ensure dust emissions remain acceptable and energy is minimized. Recent developments in control systems software, such as fuzzy logic and real-time modeling, have allowed complicated multivariable systems, such as electrostatic precipitators, to be controlled so that optimum conditions are maintained under varying operating conditions. Advanced algorithms are used to model the electrostatic precipitator performance under different operating conditions so that when conditions change the algorithm automatically adjusts the energisation control parameters to maximize performance.

Because greenhouse gas emission is dependent on the electrical energy consumed, the greenhouse gas emissions will be reduced by reducing energy consumption in the electrostatic precipitator. The Environmental Coordinator operates to minimize energy consumption, thus reducing greenhouse gas emissions, while maintaining the particulate emissions within set limits. To achieve this outcome each electrical zone in the electrostatic precipitator must be optimized depending upon the process conditions. Energy reductions of up to 90% are possible while maintaining dust emissions below the required level.

The Environmental Coordinator works in conjunction with the optimization algorithms built into the Optipower ® controllers to ensure minimum power consumption and a rapid response to any dust emission increases. It also monitors the performance of each electrical zone in the electrostatic precipitator to detect, analyze and inform the operator of any problems. This technology ensures that the best operation is maintained at all times from an expensive electrostatic precipitator plant.

3.4 Electric Wind Enhanced Electrode

The collection of ultrafine particles with diameters less than 0.5 micrometers is largely a result of a phenomena called “Electric Wind”. The corona formed at the emitter electrode due to the application of high voltage electric energy produces negative ions in the gas. These ions move as a result of electrical forces towards the collector electrode. This movement produces the “Electric Wind” which carries the ultrafine, light particles towards to collector electrode. Upon reaching this electrode, these particles attach to the existing dust layer and are collected. The key to this process is the production of the “Electric Wind” with sufficient strength and direction that the particles are moved to the collector electrode.

There are two problems associated with this process:

Gas recirculation - There is a significant gas flow back towards the emitter electrode to fill the void created by the ion movement. This process only occurs in the region of the emitter electrode but can result in dust build-up on the emitter electrode if ultrafine particles are recirulated in this process.

Low ion velocity - The rate of ion movement towards the collector electrode slows in the region of the collector electrode due to reduced electrical forces and ion dispersal. To ensure the dust particles are moved to the collected dust layer, the ion flow and direction must ensure sufficient flow at the collector electrode.

The Electric Wind Enhanced Emitter Electrode developed by Baltec Systems is designed to meet these criteria. This technology results in enhanced collection of fine dust particles which are normally a large component of the dust emissions from electrostatic precipitators.

4.0 CONCLUSION

This paper outlined solutions to a range of common operating problems Baltec Systems personnel have encountered on electrostatic precipitators. If these solutions are used in conjunction with the performance enhancement technology described, significant reductions in dust emissions are possible. The potential for improving the electrostatic precipitator performance depends upon the current operating conditions. An accurate assessment of this potential requires an operational audit by an experienced electrostatic precipitator engineer. The potential variation in measured and observed operational conditions due to one or more operational problems combined with the fact that different operational problems can produce similar results makes assessment difficult. If there appears to be one or more operational problems or potential for enhanced performance, it is recommended that a detailed audit be carried out by expert personnel.

5.0 REFERENCES

Truce R. J. Electrostatic Precipitator Energisation for the Collection of Highly Resistive Dusts, American Society of Mechanical Engineers, Paper No. 86-JPGC-EC-3, Presented at the Joint ASME/IEEE Power Generation Conference, Portland, Oregon, October 19-23, 1986.

Hein A. G. and Gibson D. Skewed Gas Flow Technology Improves Precipitator Performance ESKOM Experience in South Africa, Page 238-243, Proceedings of the Fifth International Conference on Electrostatic Precipitation, Budapest, Hungry, July 18-23, 1996.

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APPENDIX A

ELECTROSTATIC PRECIPITATOR ENERGISATION CHARACTERISTICS

The energisation characteristic of an electrostatic precipitator is obtained by increasing the energisation from zero to the maximum possible in small steps and recording the electrostatic precipitator voltage and current at each step. It is recommended that in addition to the average values, the minimum and the maximum of the voltage waveform are recorded along with the peak current. The minimum voltage should be used to detect Back Corona and the maximum voltage used to record the sparkover voltage. These parameters are then plotted to give the current/voltage or energisation characteristic. This should be done for all electrical zones at the end of each major outage before start-up, to check for adequate clearances, and once normal operation is achieved, to check for operating problems.

Figure 1 depicts the normal energisation characteristic curves which indicate no electrical problems. The Front Field requires a higher voltage to achieve the same current due to the effects of high space charge, produced by the high number of charged dust particles, on the electric field. It reduces the field strength at the emitter electrode, thereby reducing the corona charge generation. The higher voltage on the dirty plate characteristic compared to the clean plate characteristic is caused by the voltage drop across the dust layer due to the dust resistance. The on-line voltage required on the rear field is slightly higher than the off-line dirty plate due to the increased dust resistance at higher temperature.

Figure 2 depicts seven curves which vary from the normal energisation characteristic due to operating problems which occur in electrostatic precipitators. These curves are only typical examples and the energisation characteristic can vary significantly depending on the operating conditions.

Description of Abnormal Energisation Characteristic Curves

Curve (1) illustrates a resistive path to ground. It might represent a cracked support insulator or a high hopper ash level. If the resistance of the path is sufficiently low, it may not be possible to energise the electrostatic precipitators without causing an over-current trip.

Curve (2) illustrates severely reduced clearance between the emitting electrodes and any earthed section of the electrostatic precipitator including the collector electrodes. The curve is characterised by a low voltage corona onset and sparkover at a low maximum voltage.

Curve (3) illustrates severe Back Corona caused by high dust resistivity. A backward curve, with decreasing minimum voltage for increasing currents, is a certain indication of this condition. Sparking may, or may not, occur below the current limit.

Curve (4) illustrates high resistivity and moderate Back Corona, as indicated by the vertical portion at the end of the curve and the reduced average voltage. As in the previous case, sparking may or may not occur before the current limit is reached. This is likely to occur in the front electrical zones of an electrostatic precipitator.

Curve (5) indicates high resistivity where Back Corona has caused heavy dust deposits on the emitter electrode. Spark-over at lower average voltages is caused by the Back Corona reducing the minimum voltage between peaks. This could also be indicative of reduced clearance between the emitting electrodes and any earthed section of the electrostatic precipitator including the collector electrodes. The current and voltage waveform would need to be analysed if there was a question as to the cause of the problem.

Curve (6) illustrates the effect high inlet dust load on the front electrical zone of a electrostatic precipitator. The corona starting voltage is abnormally high due to the increase in space charge caused by the charged dust particles suspended in the gas. The curve has a normal shape, until breakdown voltage is reached at some weak point in the system. This occurs at a much lower than normal current due to the space charge.

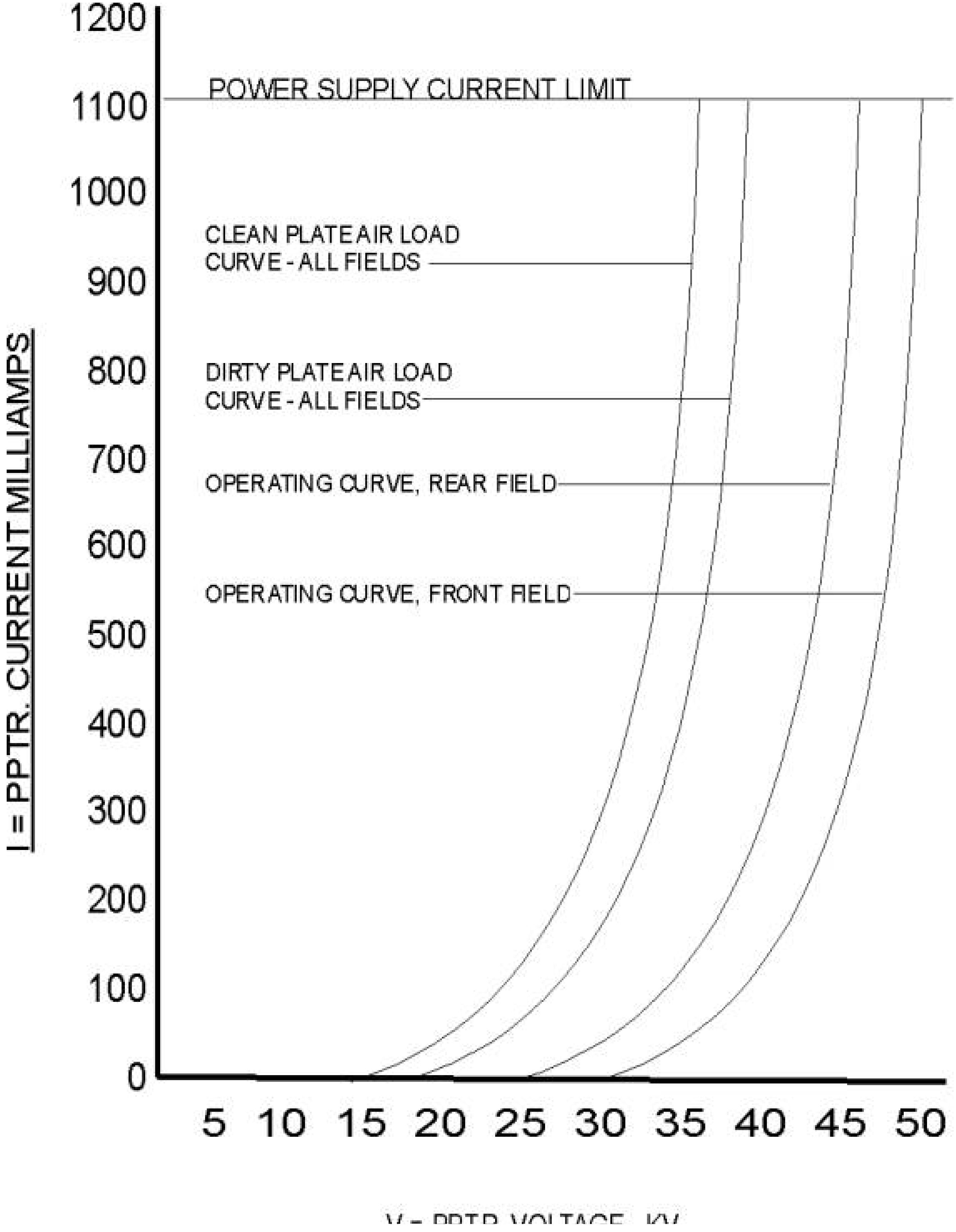
Curve (7) illustrates the effect of heavy dust deposits on the emitter electrodes. The corona starting voltage is abnormally high due to the increase in effective radius of the emitting electrodes. The curve has a normal shape, until breakdown voltage is reached at some weak point in the system. This occurs at a much lower than normal current due to the high effective radius of the emitting electrodes. In particularly severe cases, the breakdown voltage may be lower than the corona start voltage and no curve can be obtained.

Fault Analysis

Following an electrostatic precipitators overhaul or refurbishment the energisation characteristic should be recorded at the following stages:

- Following megger tests to record clean plate air load characteristic.
- Upon return to service to record clean plate operating characteristic.
- After one months operation to record normal operating characteristic.
- When an operating fault is indicated by the energisation controller.

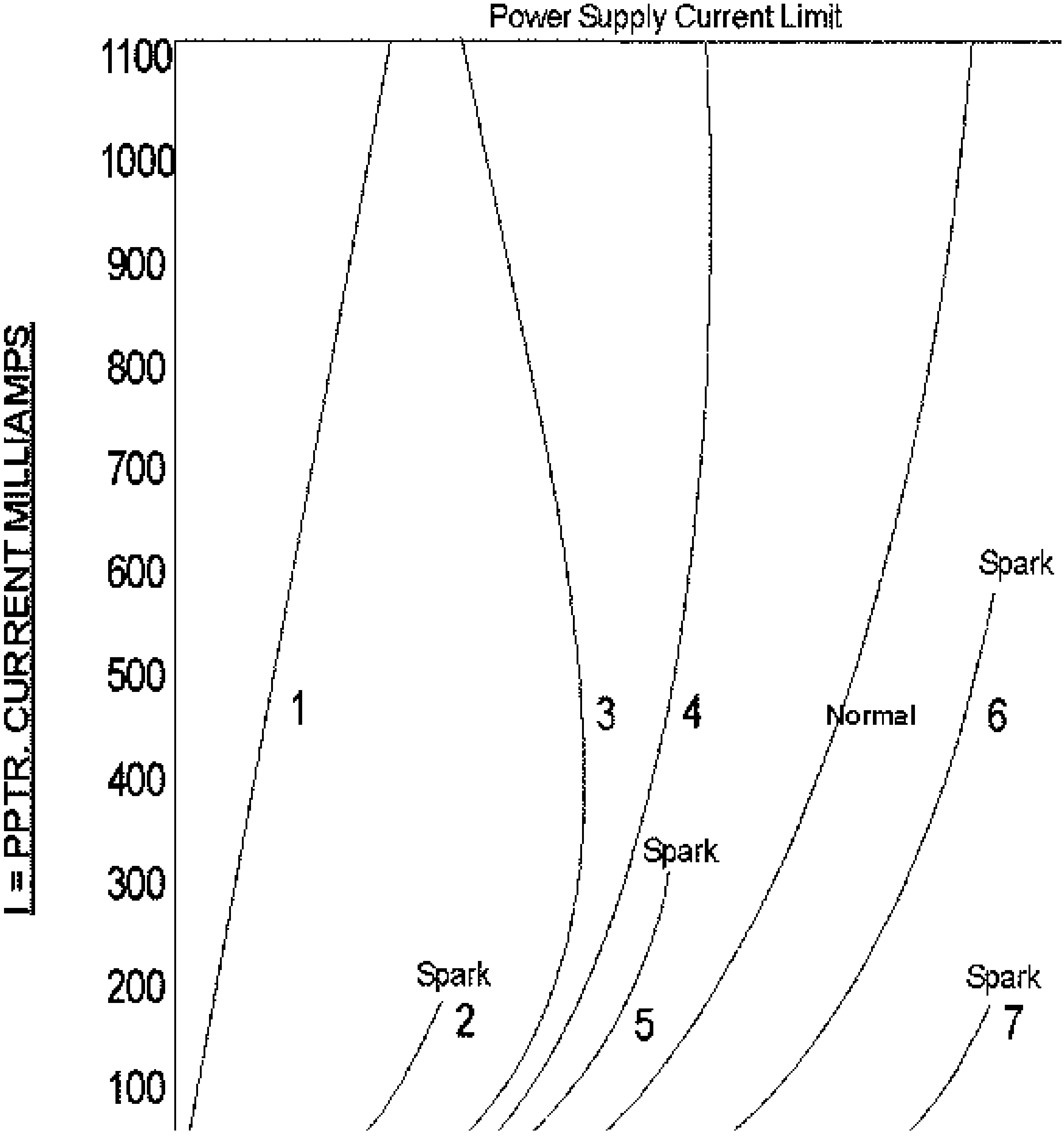
Modern energisation controllers, such as the Optipower ® unit from Baltec Systems, should do energisation characteristics upon request and either display the result or provide a computer file which can be graphed using a standard software package. The controller should record maximum and minimum electrostatic precipitator voltage plus maximum electrostatic precipitator current in addition to the average electrostatic precipitator voltage and current. These energisation controllers should also be capable of diagnosing any electrostatic precipitators faults which occur by analysing the electrical characteristics. Because similar characteristics can result from different faults, for example sparking at low currents can occur as a result of reduced clearance, high dust load, emitter electrode dust deposits, severe Back Corona or a combination of these, it is important that the energisation characteristic be recorded and analysed in conjunction with the known physical operating conditions. If the process conditions are known, it is easy to eliminate some of the possible faults and identify the most likely fault.



V = PPTR. VOLTAGE KV

FIGURE 1

NORMAL PRECIPITATOR CURRENT-VOLTAGE CURVES



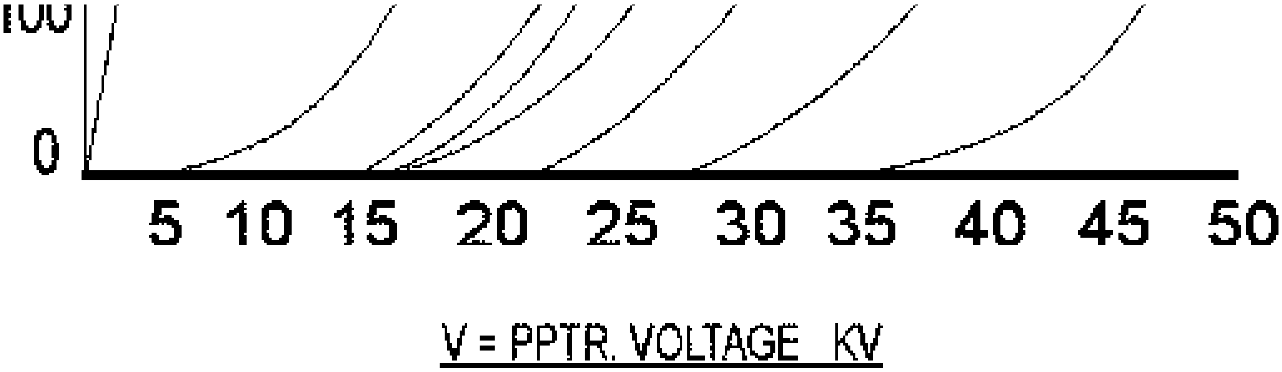


FIGURE 2

ABNORMAL PRECIPITATOR CURRENT-VOLTAGE CURVES