ENHANCED CORONA DISCHARGE USING INNOVATIVE RIGID DISCHARGE ELECTRODES (RDE)

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ENHANCED CORONA DISCHARGE USING INNOVATIVE RIGID DISCHARGE ELECTRODES (RDE)

Authors

Gustl Mischkulnig and Porfirio Bento, GEECOM (Pty) Ltd
Johannesburg, South Africa

ABSTRACT

The collector efficiency of an ESP is directly related to the applied corona power. However, this corona power needs to be applied effectively in order to impart the largest benefit possible at the actual point of corona discharge which emanates from an element referred to as a discharge electrode.

Discharge electrodes have evolved quite ungrammatically over the years and it is still quite common today to be faced with ESPs equipped with such elements which were designed and installed over 30 years ago. However, new demands for higher efficiencies coupled with corresponding lower maintenance costs, have led to some manufacturers favouring technologies and applications more suitable for today's general usage. This implies looking into models which consider not only updated technology aspects but also manufacturing process, reliability in the long term as well as easy installation in order to effect cost effective replacements.

Rigid Discharge Electrode (RDE) technology has been utilised extensively in Europe and North America and it has been found that the electrical characteristics of such electrodes have contributed significantly to an improvement in the efficiency of many ESPs. Furthermore, because of greater flexibility in geometry and configuration of the electrode units, RDE technology allows for such improvements as increases in Specific Collection Area (SCA), aspect ratio, migration velocity and treatment time.

This paper deals with an innovative type of RDE conceptualised in South Africa, considered specifically to optimise the practical issues associated with effective corona discharge processes and at the same time improve the expected life cycle of such devices combined with a simple configuration providing for easy replacement of obsolete or faulty units.

1. INTRODUCTION

The design and optimisation of discharge electrodes is a subject which every OEM (original equipment manufacturer) is normally quite passionate about. Such designs are normally a compromise between the integration of basic fundamental principles and practical issues. The fundamental principles are well known and can be ascribed to the following:

- Achieving best possible results of corona current (mA) versus applied power (kV)
- Maximizing the strength of the corresponding corona field.
- Minimizing the value of onset voltage.
- Optimising the distribution geometry of the corona field onto corresponding collector plate.

Practical issues requiring special attention fall within the following categories:

- Space utilization within the precipitator (i.e. when compared to other types such as rigid frame discharge electrode).
- Addressing possible failures and ease of replacement (i.e. when compared to normal practice of "cutting" wires)
- Compatibility with normal rapping devices and relevant shock transfer.
- Manufacturing practicality and installation simplicity.
- Durability and life cycle.

In addition to the continuous search for the ideal integrated solution, there appeared in the early 80's a movement towards significant increases in ESP efficiencies (>99.5%) combined with large decrease in emission levels driven by the introduction of highly restrictive air quality standards.

Subsequent evaluations led to the identification of the Collector Electrode System as the element which, most likely, could provide the highest contribution to the required ESP enhancement.

Such events led to the introduction of Rigid Discharge Electrodes (RDE) sometimes also titled "Mast Electrodes" or "Pipe and Spike" which were introduced in many forms and shapes as shown in Fig 1.

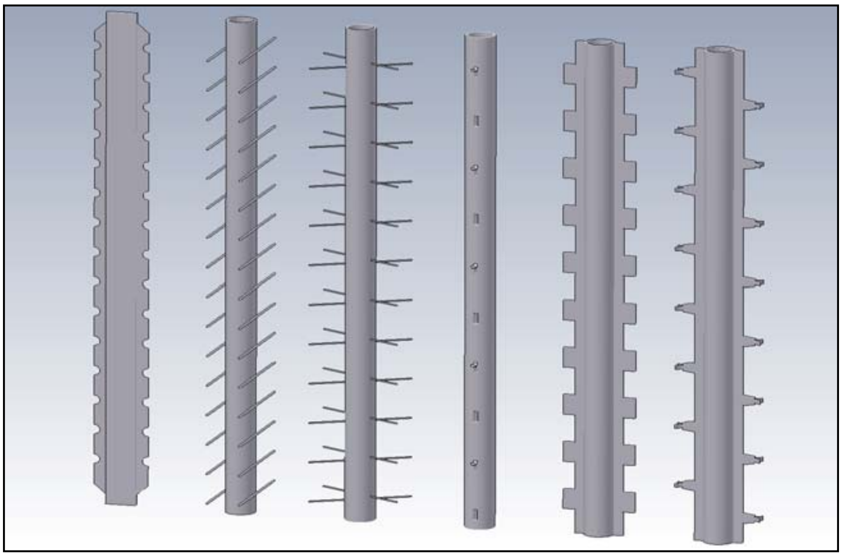


Figure 1 – Various types and/or configurations of available Rigid Discharge Electrodes

2. ENHANCED RIGID DISCHARGE ELECTRODE (RDE)

2.1 Introduction

The concept of RDEs was formulated originally not only to provide a high aggressive corona current producing electrode but also to address a general phenomenon associated with poor coverage of current discharge at collector plates adjacent to normal discharge electrodes as indicated in Photo 1.

Photo 1: Details of poor current discharge coverage on collector electrode plates

Much needed improvements were duly introduced and actual success achieved, in the long run, by the early RDEs,. However, subsequent evaluation of RDE's performance under normal operating conditions have uncovered the following areas of concern:

- Materials used in the construction / manufacturing process were still susceptible to varying degrees of corrosion limiting the acceptable life span of some units.

- Introduced design and construction methods still tolerate unacceptable levels of progressive deterioration in some types as identified by the following:
  - Detachment of spikes from tubular base due to inconsistent or poor welding as well as galvanic erosion due to use of different materials.
  - Corrosion of mast section leading to "splitting" of seams on either side thus damaging electrode alignment.
  - Some spikes are easily bent during such operations as high-pressure washing. This "bending" minimizes the spark clearances making the relevant field less effective and/or totally inoperative.

2.2 Concept for New Design

In order to eliminate most of the common causes of concern or actual failures in the field as well as to impart a high level of durability combined with greater corona current capabilities, a new RDE was conceptualised based on the following main prerequisites:

- Selection of a durable material with high levels of resistance against gas contamination and corrosion.
- Low basic mass in order to impart maximum benefit to available structures in case of retrofits as well as structural design restrictions in new electrostatic precipitators.
- Rigidity, flexibility of the material to be used and, most important, compatibility in all individual components.
- Propensity for uniform transmission of acceleration waves imparted by striking the material.
- Minimising corona onset voltage and maximizing field corona propagation as well as necessary coverage.
- Bias towards ease of manufacture, relevant assembly and installation on site.

All requirements were met by selecting the right type of stainless steel as the basic building block for the new RDE. Stainless steel is a material virtually immune to corrosion as well as erosion and is non-reactive in the presence of most chemicals having also the ability to withstand normal temperatures that are associated with some electrostatic precipitators.

Although the concept includes some of the accepted "standard" designs for RDEs e.g mast and corona generator, this new design also considers the following unique features:

- Small diameter seamless laser welded stainless steel tube (25 mm) which minimizes onset voltage as well as being totally impervious to dust entrainment.
- Highly aggressive corona generator in the form of a double extension spike element manufactured from austenitic stainless steel.
- Collar type spike element which is fitted smugly around the support tube (mast) and appropriately spot welded as added safety.
- Each spike element considers suitably sized extensions in the horizontal plane with each end comprising multiple tines (4 per end) which are sharply pointed and individually arched to suit collecting electrode geometry.
- Ergonomically designed spike element to favour gas flows and relevant distribution.
- Adaptable flattened inserts at top and bottom to suit any hanging or attachment requirements.

The new RDE has been identified as the G-Spike ™. Refer to Figs 2 and 3 as well Photos 2 & 3

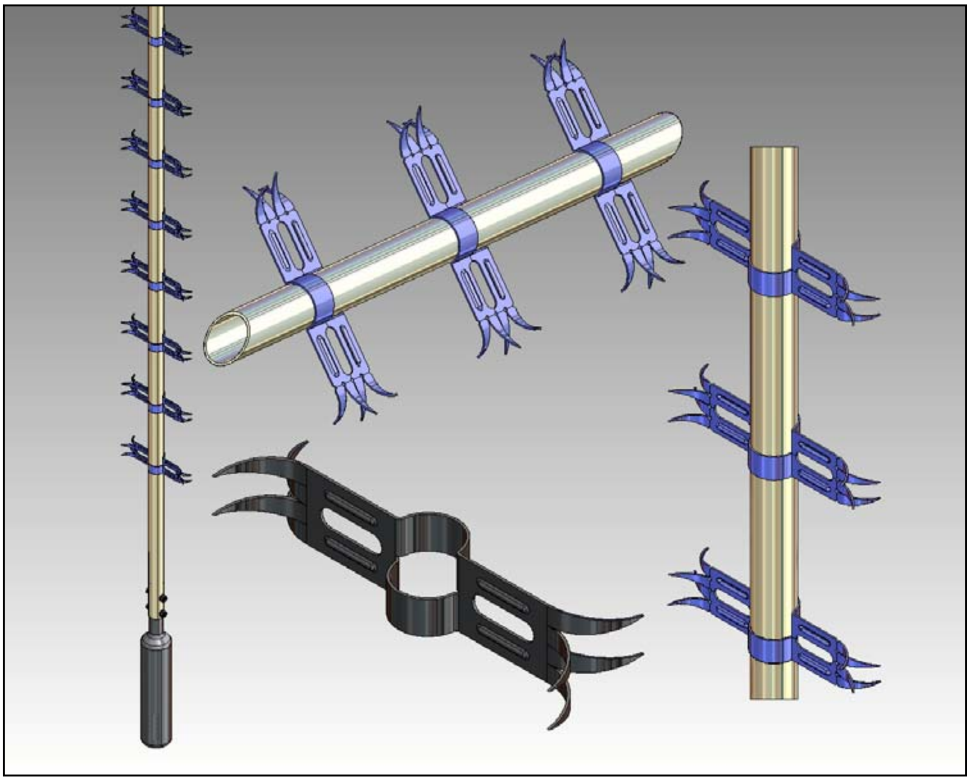


Fig 2 : Details of Innovative Rigid Discharge Electrode Photo (G-Spike ™)

Fig 3. Details of corona generator (spike)

Photo 2. Installation arrangement

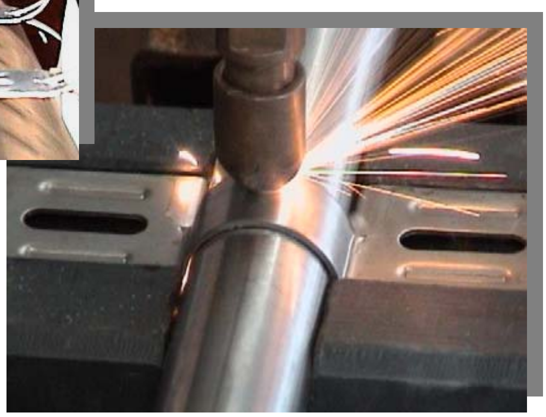


Photo 3. Welding of spikes

2.3 Experimental Electrical Tests and Results

The design concept for the new RDE was extensively tested in a specially constructed "rig" which incorporated the following:

- An adjustable gas passage which could be set at either 300 or 400 mm with a total height of 8 metres
- Possibility to include a minimum of 3 passages as well as different ESP configurations i.e. plate or tube
- Adjustable rapping system (hammer weight, position and timing) to allow for acceleration and/or impact propagation tests
- An HV control system comprising Transformer Rectifier and Control Panel with the following technical characteristics:
  - Input voltage: 525 V
  - Input current: 31.2 A
  - Output voltage: 76 kV peak
  - Output current: 400 mA

The G-Spike ™ RDE was tested in still, ambient air and under three different conditions i.e. mast only (25 mm tube), mast with spikes (G-Spike ™) between plate electrodes (300 mm passage)and excentrically mounted spikes in mast installed within a 400 mm diameter tube (Refer to Photo 5) to evaluate the effectiveness of the spike and tine configuration.

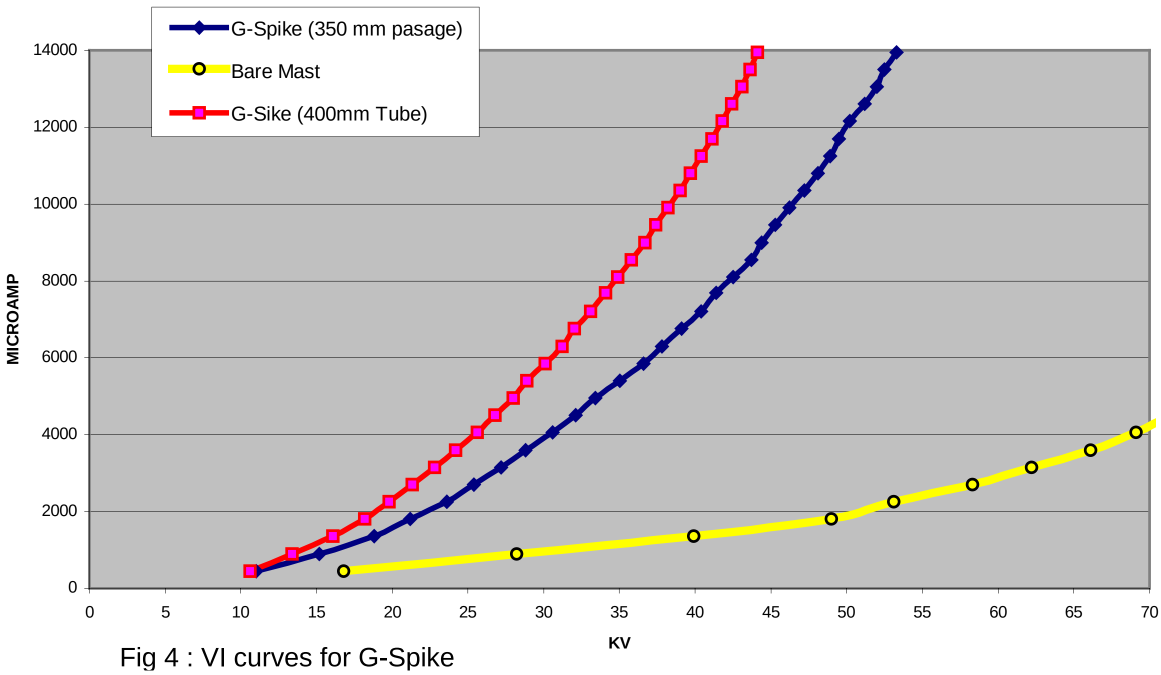


Fig 4 : VI curves for G-Spike

Results clearly indicate the effectiveness of the corona generator (spike) and its high aggressiveness especially when applied in a specific tailored geometry such as that for the tube precipitator. The improvements relative to the Corona current can be seen in Table 1.

Description	Unit	Value	Value	Value	Value	Value	Value
	kV	10	20	30	40	50	60
G-Spike	µA	360	1620	3870	6930	11700	15480
Bare Mast	µA	270	630	990	1350	1890	2790
Effective Corona Current Improvement	µA	90	990	2880	5580	9810	12690
Improvement	%	33.3	157.1	290.9	413.3	519.0	544.0

Table 1. Effective Corona current values for discharge electrode G-Spike ™

The aggressiveness of the RDE is further evidenced by the display of the corona at the extremity of the tines as indicated in Photo 4.

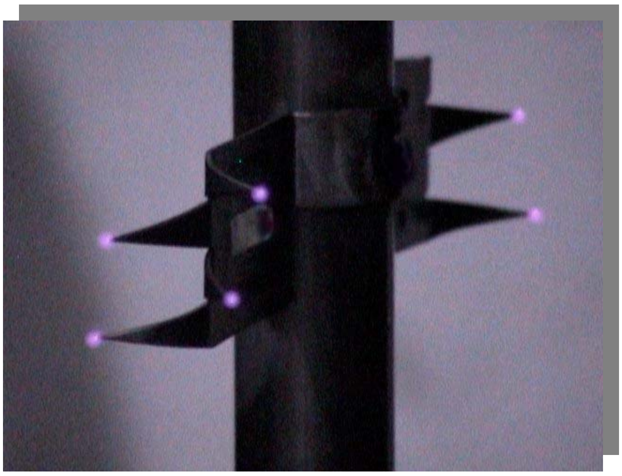


Photo 4. Display of corona effect at spike

Photo 5. Tube mounted application

A set of typical RDEs from various manufacturers was then duly tested under identical conditions with following results:

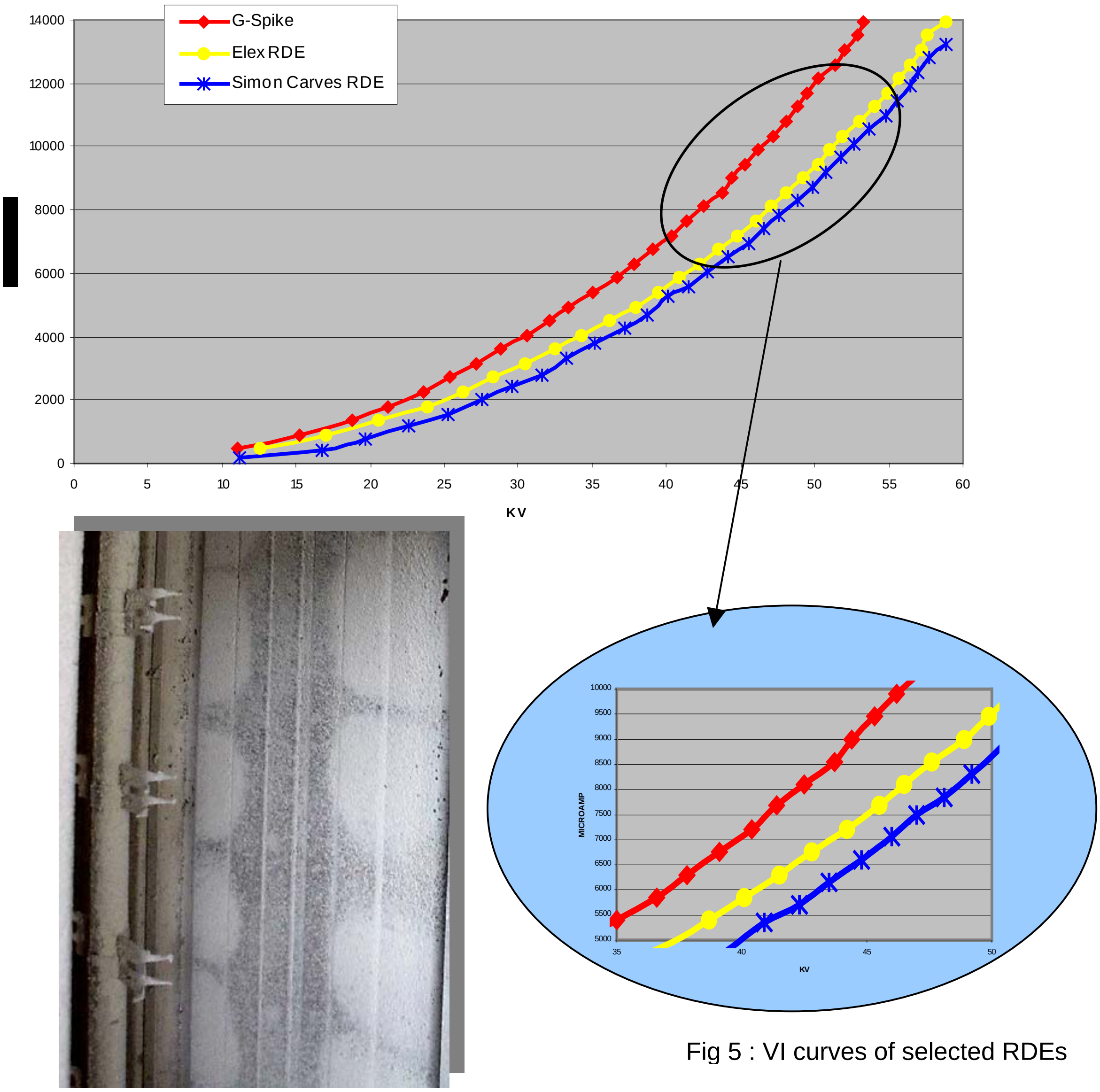


Fig 5 : VI curves of selected RDEs

Photo 6 : Coverage of corona current on plate with RDE

The G-Spike TM RDE shows a definite improvement in corona current over the other two proprietary RDEs which varies between 12,5% at 15kV and 47,4% at 45 kV. This variance is attributed not only to the configuration of the mast but also to the high level of aggressiveness of the corona generator (spike) and its matching compatibility to the geometry of the collector electrode plates. This compatibility is also of the utmost importance in order to ensure maximum uniformity of current discharge and a substantial decrease in the occurrence of “cold spots” where corona current flow is minimal.

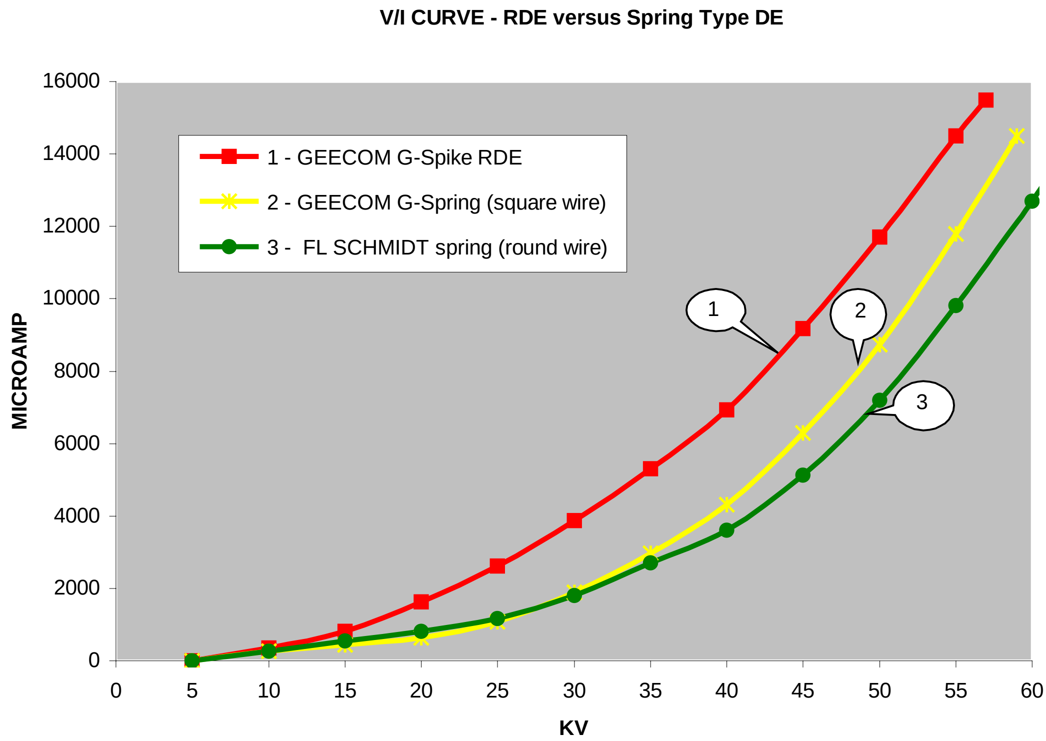
Compatibility is assured not only by the position of the corona generator (spike) at mast intervals suitable to the ESP configuration but also to its specific width as well as the explicit curvature of the 4 tines at each end. Field tests on Electrostatic Precipitators equipped with G-Spike TM RDEs indicate a clear improvement to the coverage area as demonstrated in Photo 6 above.

Further tests were then carried out to evaluate effectiveness of the G-Spike TM RDE against other spring type discharge electrodes. In this instance, two different spring type configurations were tested using the above mentioned test rig ;

- A spring discharge electrode (Geecom G-Spring) installed on a centrally mounted mast and comprising square shaped electrode wire.
- A spring discharge electrode (FL Schmidt) installed on a centrally mounted mast and comprising round shaped electrode wire

The results are indicated in microamps and show an overall effectiveness of the G-Spike TM RDE over the spring type discharge electrode from 22.9 % to 157.14%

kV	10	15	20	25	30	35	40	45	50
Geecom G-Spike RDE	360	810	1620	2610	3870	5310	6930	9180	11700
Geecom G Spring square	270	450	630	1080	1890	2970	4320	6300	8730
FL Schmidt – spring round	270	540	810	1170	1800	2700	3600	5130	7200
Increase: RDE ; FL Schmidt	+90	+270	+810	+1440	+2070	+2610	+3330	+4050	+4500
Increase: RDE ; G-Spring	+90	+360	+990	+1530	+1980	+2340	+2610	+2880	+2970



2.4 Rapping Acceleration Tests and Results

The rapping acceleration normally needed to dislodge dust from relevant electrodes (discharge or collecting) varies with dust properties. However, it is generally accepted that a value of 100 'g' is sufficient to dislodge most dusts and thus RDEs need to be configured so as to allow, as a minimum, such acceleration level or possibly achieve even higher amounts of rapping intensity propagation. In the case of the G-Spike TM RDE, stainless steel was also selected for the "mast" as this material offers a low propensity towards dampening of applied forces.

As part of the development process for the new RDE (G-Spike TM), rapping intensity and acceleration propagation tests were conducted in a laboratory using the same test rig as that described above for corona current tests and including the following specific set up:

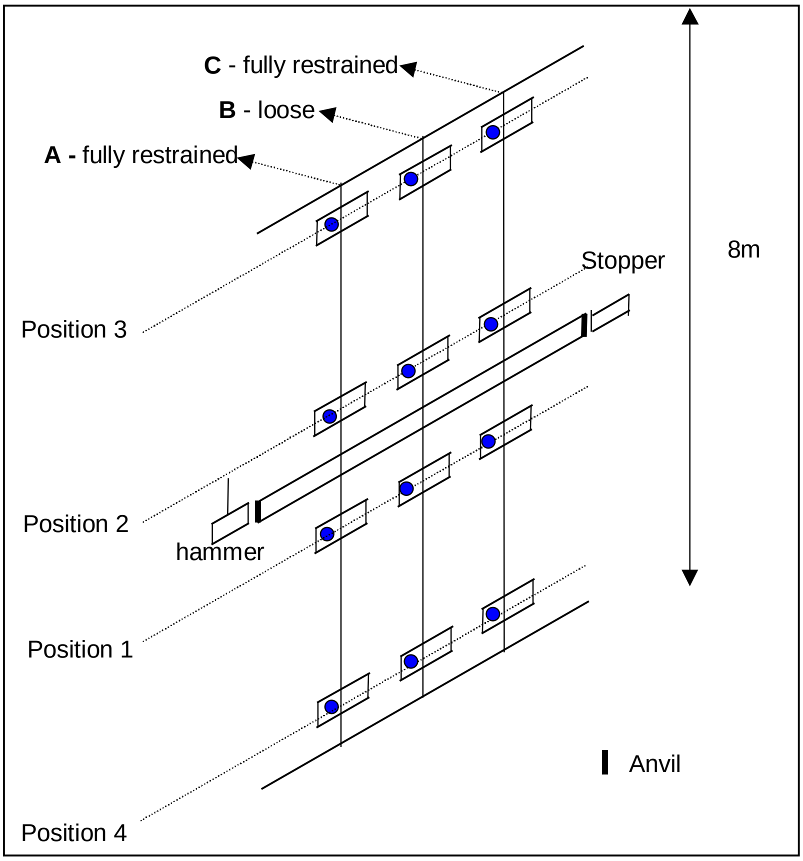


Fig 6 : Acceleration test set-up

- A single electrode "curtain" was mounted on a solid structure suspended from a support frame mounted on bearing springs.
- The electrode "curtain" comprised three (3) G-Spike TM RDEs, solidly affixed to the support frame by means of restraining bolts.
- Each RDE comprised 65 "corona generators" (spikes) spread over a height of 8 m
- The "curtain" was centre rapped at a height of 4 m with a single 4.9 kg tumbling hammer. The rapper bar was equipped with anvils on both the striking and non-striking ends with a stopper attached to the support frame at the non-striking end in order to impart a double impact horizontal action to the RDE curtain. Three (3) PCB 353M192 and a single Rion PV-90B accelerometers were used to obtain acceleration measurements with relevant testing "heads" glued to the relevant RDE test point as shown in Fig 6. These accelerometers were connected to charge amplifiers (Sabertek 625-00 and B&K 2635) and relevant outputs recorded on a Sony DAT recorder (S/N E4619).

The first test was carried out with the "stopper" positioned 10 mm from the end of the rapper bar at the non-striking end. Four points on the G-Spike TM RDE as shown in Fig. 6 above were measured to observe the actual rapping intensity along the mast.

A second set of tests was carried out with the stopper removed (single impact) in order to quantify the effectiveness of rapping methodologies. The values obtained were processed on a computer running PC Scan II, Version 3.0 and an average of five rapping impacts were used to obtain the final results at each point:

POSITION	1	2	3	4
	G's (Pk –Pk)	G's (Pk –Pk)	G's (Pk –Pk)	G's (Pk –Pk)
With Stopper				
A – restrained	688	1034	446	440
B – loose	588	763	417	255
C – restrained	889	1146	524	328
Without Stopper				
A – restrained	971	1144	484	602
B – loose	633	671	415	250
C – restrained	705	789	507	335

Table 2 - Results of impact tests

Results obtained are interpreted as follows:

- From Table 2 it can be seen that the acceleration values are at their highest at points closest to the rapping impact (positions 1 and 2) as expected and they decrease as this distance increases (positions 3 and 4).
- The loose RDE indicates acceleration values much lower than those of the restrained units.
- Comparison between with/without stopper indicate a tendency towards lower acceleration values at the RDE closest to the rapping impact but a higher value at RDEs further away. This can be clearly seen at all points (1 to 4) of RDEs A and C.
- During testing it was further noticed that the stopper element caused a stabilizing effect on the RDEs resulting in less sway of the units and faster return to a non-vibrating condition.

Conclusions obtained form the acceleration tests as follows:

- The material selected (stainless steel) for the G-Spike TM RDE is extremely partial to transmission of acceleration along entire length of the element.
- The acceleration values obtained using normally sized rapping hammers are much higher that those normally accepted as being effective. This means that hammer weights could easily be decreased in order to obtain acceptable levels of dust removal.
- Double impact arrangements are preferable in order to impart higher acceleration values to complete discharge electrode "curtains" especially with longer arrangements (i.e > 8 RDEs)
- Centrally mounted rapping hammer arrangements are highly effective but have other disadvantages when compared to top rapping assemblies.
- RDEs have a higher acceleration efficiency coefficient than frame type discharge electrode systems.
- RDEs should be fully restrained at all times in order to allow for optimum propagation of rapping forces.

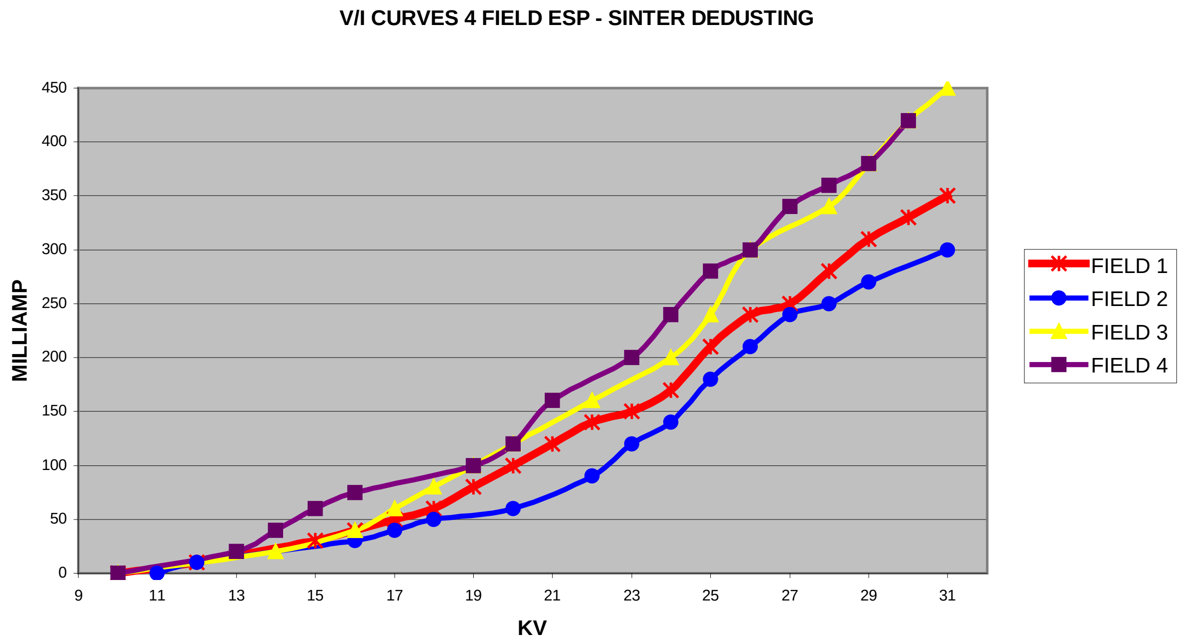
3. FIELD IMPLEMENTATIONS AND RESULTS

Following completion of laboratory tests and relevant positive evaluation, G-Spike TM RDE systems were supplied for various refurbishment projects in the following industries:

- Pulp & Paper: Recovery boiler (Soda ash) - 2 off
- Pulp & Paper: Power boiler – 2 off
- Sinter plant: Dedusting precipitators - 3 off
- Nickel smelter: Dryer precipitator – 2 off

- Platinum smelter: Dedusting off gas precipitator

The aggressive corona current characteristics of these RDE installations is clearly indicated by the following V-I curves specific to a 4 field ESP with 350mm gas passages and HV control systems of 400mA/90 kV for fields 1 & 2 and 650mA/96 kV for fields 3 & 4 as well as a 2 field ESP with 275mm gas passages and HV control system of 400mA/66 kV for field 1 and 800mA/76 kV for field 2 :



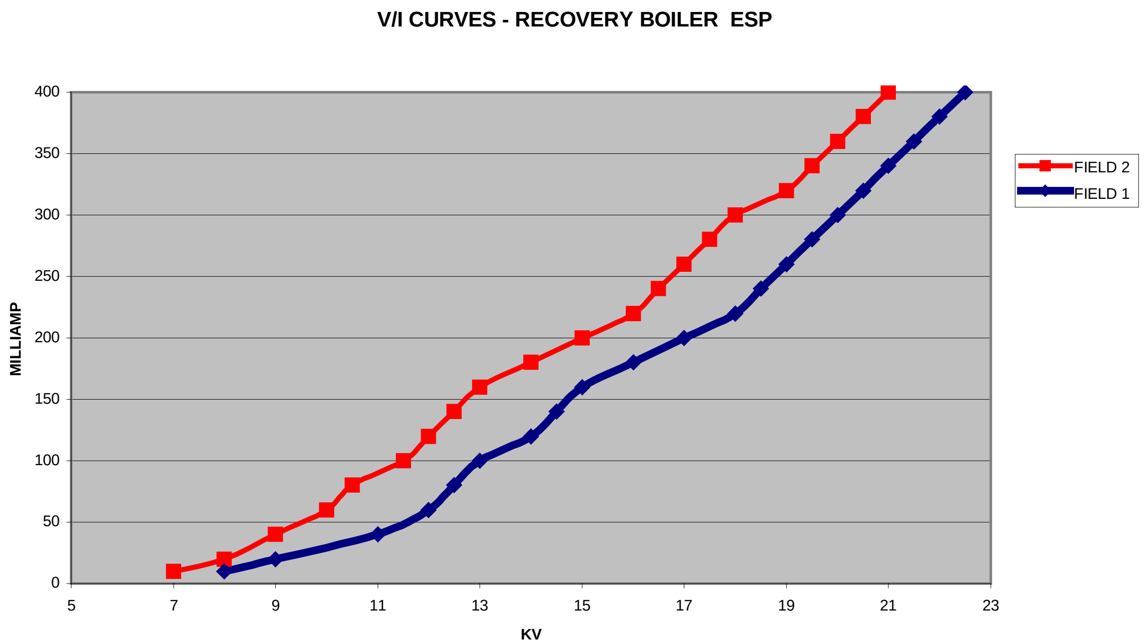


Fig 7. Operational VI curves

In both the above-mentioned projects which were realized between 2001 and 2003, the implementation of RDEs in place of frame type electrodes led to a direct increase of over 35% in corona power when compared to values obtained prior to the overall refurbishment. Furthermore, SCA (specific collecting area – i.e. total collecting area/gas flow rate) improvements varying from 22.8% to 43.8% were also possible with added benefits obtained from implementation of a sectionalization approach.

Additionally there have been no recorded Discharge Electrode failures in any of the installations and all systems are operating satisfactorily.

4. EVALUATIONS AND CONCLUSIONS

Extensive engineering as well as laboratory and field testing have led to the introduction of a highly innovative RDE design with extremely advantageous technical characteristics. Electrostatic Precipitators in need of major refurbishments have benefited greatly form the installation of this RDE mainly due to the cost effectiveness of the system when compared to expensive structural alterations which may have been otherwise required in order to meet stringent outlet emission levels.

The G-Spike ™ RDE is presently under patent application (PCT/1B01/01975) having already passed scrutiny by European patent examiners and relevant institutions.

In conclusion, the characteristics and advantages of the innovative RDE described in detail above can be summarised as follows:

- RDE with extremely low onset voltage and enhanced corona discharge at razor sharp tines.
- Spikes specifically spaced, dimensioned and formatted to ensure appropriate corona coverage area.
- Ideal configuration and material utilization to provide necessary corrosion resistance as well as ideal rapping impact acceleration transfer.
- Unyielding to mechanical interferences, impervious to dust as well as “sandblasting” effect.
- Ease of installation, increased reliability and minimal maintenance.

5. REFERENCES

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