

**CUSTOMIZED RIGID DISCHARGE ELECTRODES SHOW SUPERIOR
PERFORMANCE IN PULP & PAPER APPLICATIONS**

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ABSTRACT

Over the last 30 years aggressive, current-distributing type Rigid Discharge Electrodes (RDEs) have been used in more than 1000 new and rebuilt Electrostatic Precipitator (ESP) applications including recovery boilers, hogged fuel boilers, lime kilns, cement kilns, refinery catalytic cracking units, and coal fired power boilers. In just the past 10 years, approximately 35 recovery boiler ESPs with aggressive, current-distributing type RDEs were placed into operation in the U.S. Historical results have been generally good, but new, increasingly stringent requirements for reduced particulate emissions from all sources has placed even more importance on improved ESP performance. With the development of Customized Rigid Discharge Electrodes (RDEs), whereby several types of differently configured RDEs are used in a single ESP chamber, designers have been able to meet this challenge and provide new and rebuilt units that perform significantly better than the older ESPs they replaced.

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INTRODUCTION

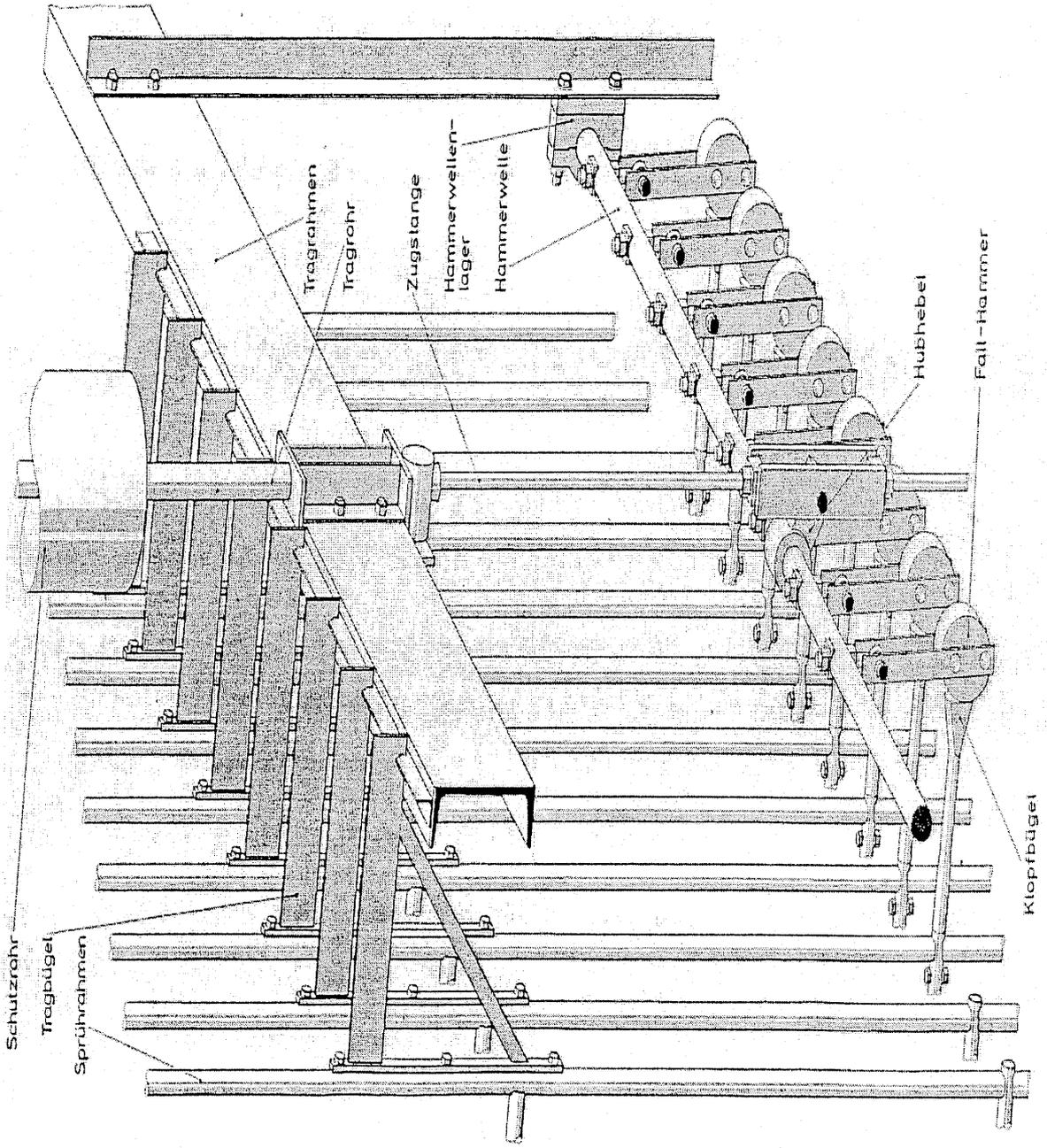
The RDE is a relatively recent addition to the evolutionary process of ESP design. Early ESP designs tended toward the rigid frame type (Figure 1) in Europe, and the weighted wire type (Figure 2) in the U.S. Although both of these addressed particular market needs, neither completely fulfilled the need for a high efficiency unit with a lower cost and low maintenance design.

The rigid frame design features large bus sections, taller collecting plates (up to 15 M (49.2 ft) and higher), larger fields, fewer bus sections and fewer transformer rectifiers (TRs) than the typical "American" weighted wire ESP design. The discharge electrodes are typically housed in tubular steel frames and rapped with tumbling hammers located inside the gas stream. Varied electrification demands have been addressed with the use of different electrode elements.

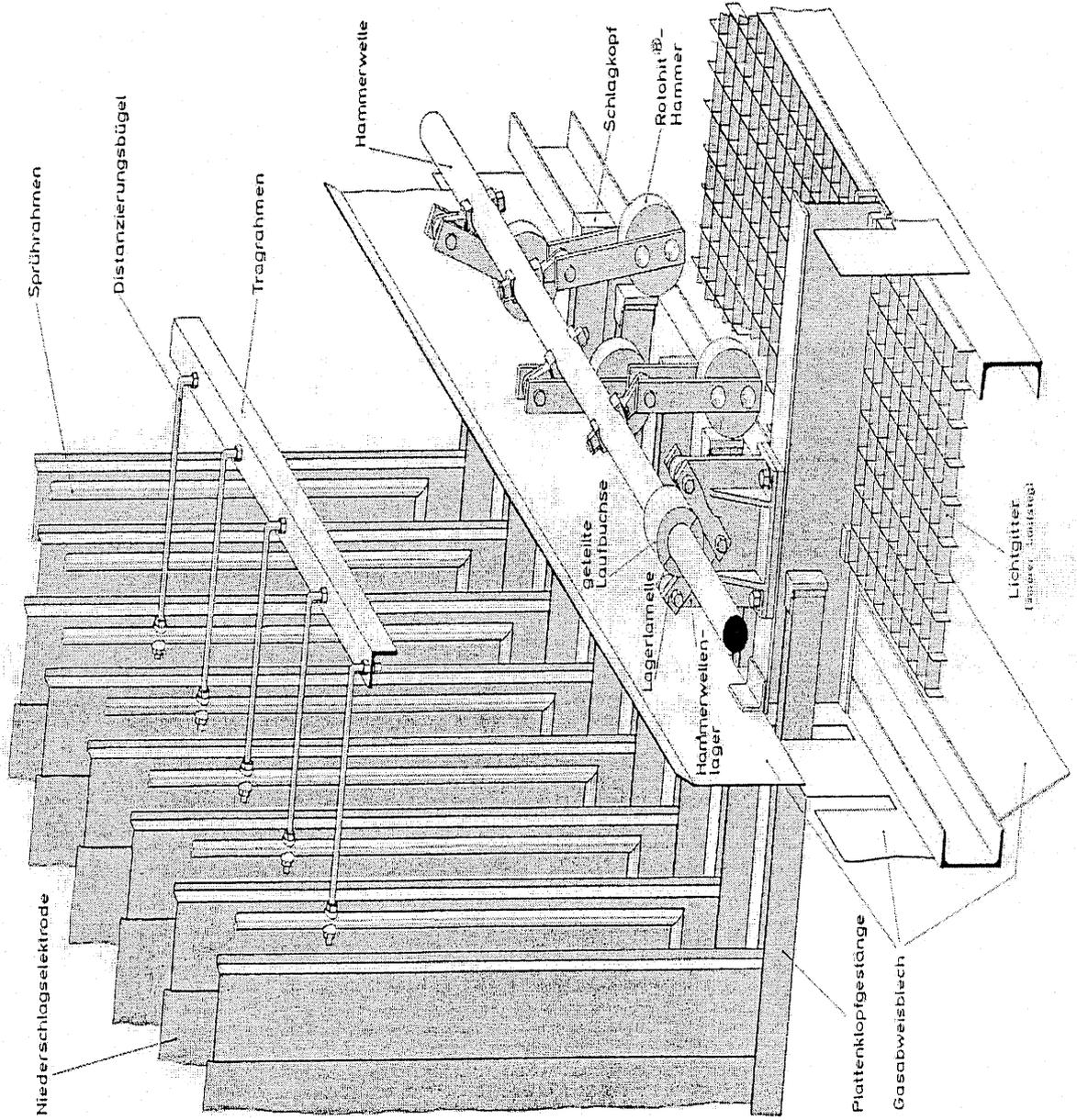
While taller collecting plates and fewer TR sets addressed the need for economy, this ESP design concept has several operational and design shortcomings:

- The method of attaching the electrode elements to the tubular frames has experienced problems with regard to reliability and consistency. Minimizing electrode breakage, and maintaining proper tension of the individual electrodes while rapping, is difficult at best.
- Tall plate designs necessitate multi-level, tumbling hammer rapping for discharge electrodes requiring a somewhat difficult and complex mechanical system.
- The wear parts of the rapper system are located within the gas stream, making online maintenance impossible.
- Larger bus sections accentuate the impact of the loss of a TR set.
- The discharge electrode support frames require a considerable amount of space inside the ESP casing, which might be better utilized for additional collecting surface.
- The various electrode elements employed often fail to provide sufficient uniformity of corona current and sufficient differentiation of electrical characteristics for optimum ESP performance.

Rigid Discharge Electrode Design



Rigid DE Design - Bottom



Weighted Wire Design

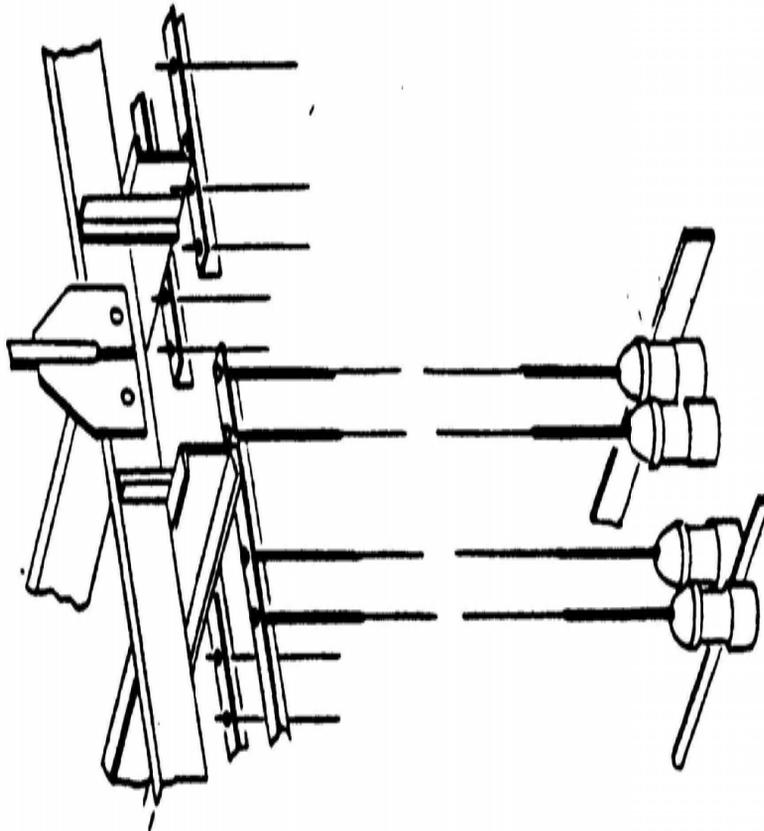


Figure 2 – Weighted Wire

Conversely, for the weighted wire American units, while the 2.77 mm (0.109 inch) diameter weighted wire design with top rapping addresses the rapping and sectionalization “shortcomings” of the rigid frame design, it falls short in the critical areas of wire breakage, reliability and optimum electrification.

Increasingly more stringent air quality standards fueled the demand for higher ESP efficiencies, lower particulate emissions, and lower stack opacities, and this forced further enhancement of discharge electrode technology. In the 1970’s and early 80’s the “mast” type electrode was developed, as shown in Figure 3.

Meanwhile, the aggressive, current distributing type RDE was enjoying success in Europe on a wide variety of applications, and was gaining a stronger foothold in the U.S. Used in combination with top rapping, this unique “hybrid” design provided a nearly ideal discharge electrode system.

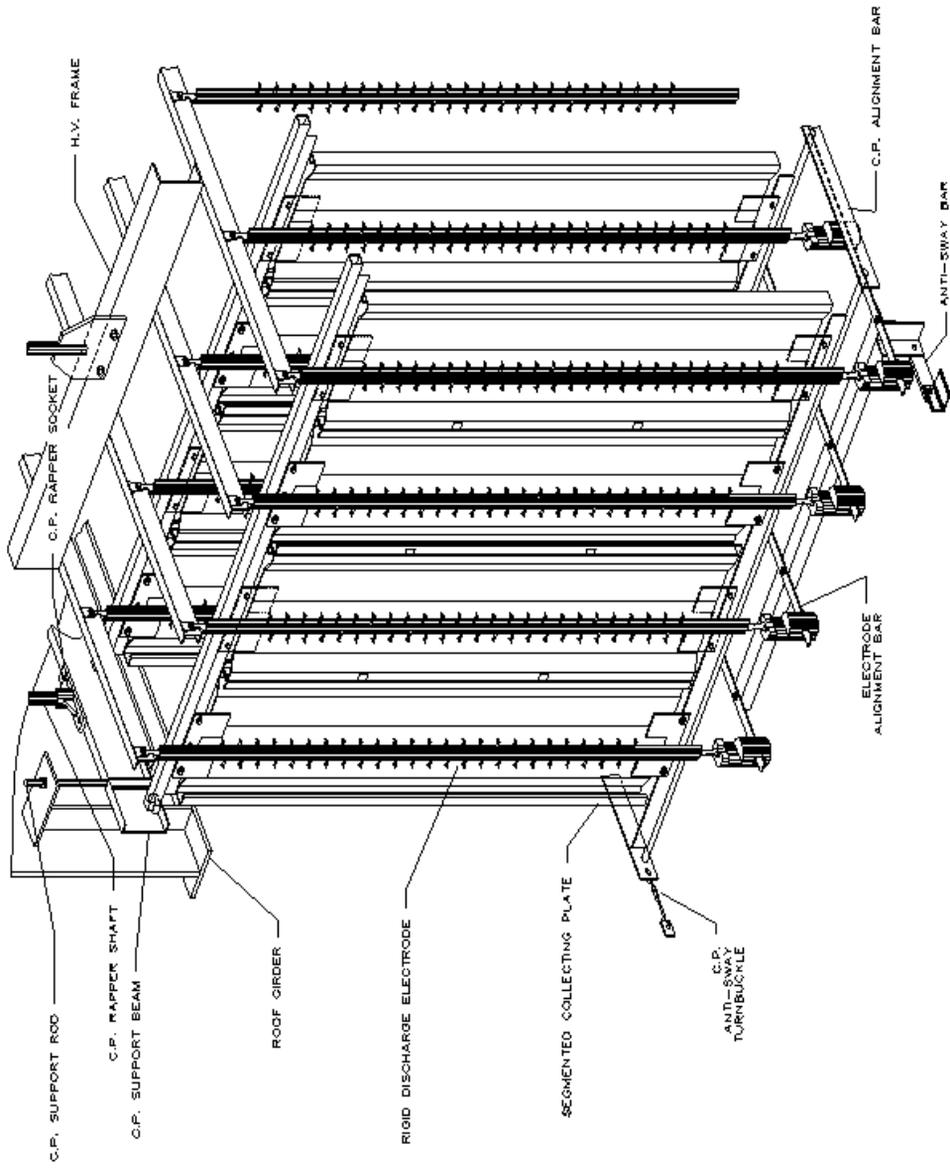
By customizing the configuration, a near “perfect match” can be achieved with the RDE’s electrical performance and its location within the ESP. All rapping wear parts are external and can be adjusted and maintained on line. Smaller bus sections can be economically designed and the RDEs are virtually unbreakable. The result is improved operation and maintenance with reasonable economics.

Early market pressures, however, may have slowed the widespread use of the aggressive, current distributing RDE design. This RDE is somewhat costlier than the weighted wire design, and there have always been considerable price pressures on all types of environmental equipment. Furthermore, there did not exist today’s sophisticated computer modeling tools that make it possible to calculate the improved performance of the aggressive, current distributing RDE over other discharge electrode types.

RDE PERFORMANCE GOALS

The aggressive, current distributing RDE was originally developed in Europe with the primary goal to distribute corona current discharge as evenly as possible on the adjacent collection plate surfaces.

Rigid Discharge Electrode Design



This RDE has the potential to produce moderate to very high corona current flows, depending upon the population and geometry of its emitter points. Hence, highly aggressive corona-current-producing RDEs may be positioned in the upstream fields of the ESP, where fine particle charging must occur as quickly as possible, while moderate current-producing or perhaps voltage-enhancing RDEs of a different configuration may be positioned in downstream fields, depending upon the specific application's electrification needs.

More importantly, this RDE's corona current discharge can be shown to be more uniformly distributed on the collecting plates when compared to other types of RDEs currently in use, such as mast-mounted electrodes, the so called pipe & spike designs and frame-mounted electrode elements. The onset of sparking and/or back corona ionization occurs at localized regions of high corona current, or so-called "hot spots." Rapping reentrainment of low resistivity particulate and carbon particles occurs predominantly in "cold spots," where corona current flow is minimal to nil. When a current distributing RDE is utilized, these hot spots and cold spots are not completely avoided but rather minimized, resulting in improved overall precipitation. This is of increased importance in light of today's stringent particulate emissions regulations. In the U.S., recovery boiler ESP emissions are typically required in the range between 25-35 Mg/Nm³ at 8% O₂, while ESP inlet particulate concentrations can range from 4 – 18 g/Nm³ at 8% O₂.

LABORATORY DATA

In the 1980's, ELEX AG carried out extensive laboratory testing to compare various types of RDEs with respect to their ability to provide a uniform corona current distribution on the collecting electrode surface. A small portion of that body of work has been extracted and summarized below.

A variable width ESP gas passage was constructed, with a cutout in one of its collecting plates. A test plate, consisting of a 20 by 50 grid of 1 cm² (0.155 in²) test areas, was inserted in that cutout. Each test area was electrically isolated from the test plate and its neighboring test areas, and connected to ground via a 1.1 mega-ohm resistor. The voltage across this resistor was measured, allowing the calculation of corona current flow through each individual test area.

The laboratory tests were carried out in still, ambient air with a 400 mm (15.7 inch) ESP gas passage and at an average corona voltage of 67.5 kV. The test RDEs were installed at the center of the ESP gas passage on 500 mm (20 inch) spacings, measured parallel to the collecting plate, in what would normally be the direction of gas flow.

While several different types of RDEs were tested, Figure 4 details the configuration of each of four RDEs that are reported on herein. The first three RDEs are customized configurations that have been used in recovery boiler ESPs and coal-fired power boiler ESPs here in the United States, while the fourth RDE is a non-aggressive type RDE that has been included for comparative purposes only.

The degree of corona current uniformity has been reported as a variance coefficient, which is a widely used measure of data dispersion in statistical analysis. It is defined as:

$$= \frac{\sum_{i=1}^N (X_i - m)^2}{N}$$

Where:

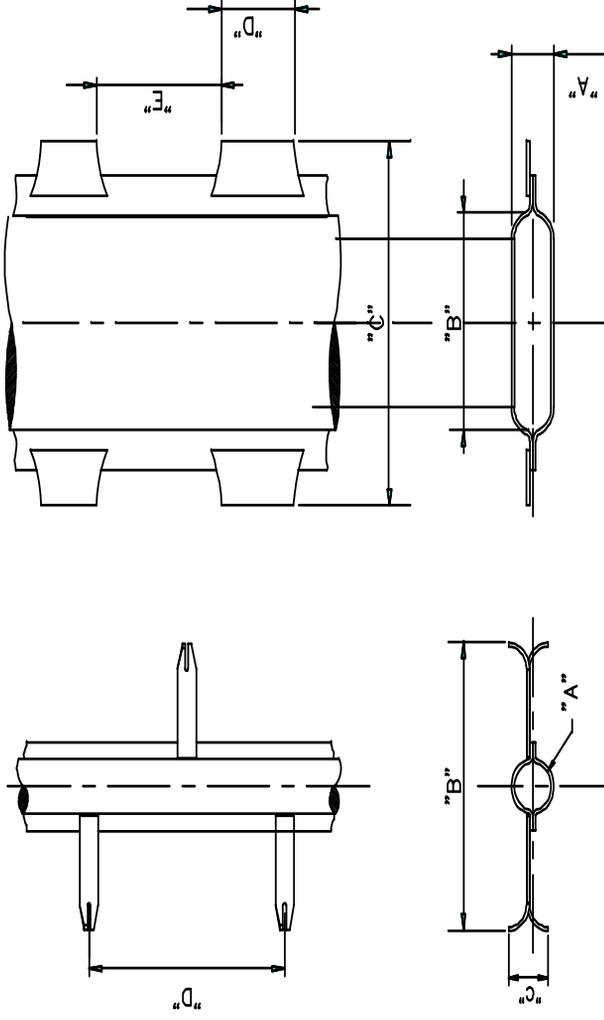
N = Number of data points in the data set

X_1, X_2, X_n = Data points in the data set

m = mean of data set

RDE 127x1 (Figure 5) has a 20 mm (0.8 inch) diameter body, staggered emitters, a 127 mm (5.0 inch) total emitter span, and a 0 mm emitter tab spread. Note how the 127mm (5.0 inch) section of collecting plate immediately adjacent to the electrode is nearly devoid of corona current. The corona current distribution has a variance coefficient of 69%, and 21.0% of the test plate receives negligible current flow. RDE 127x1 is currently in use in the United States in a coal-fired boiler ESP having 200 mm (8.0 inch) wide gas passages.

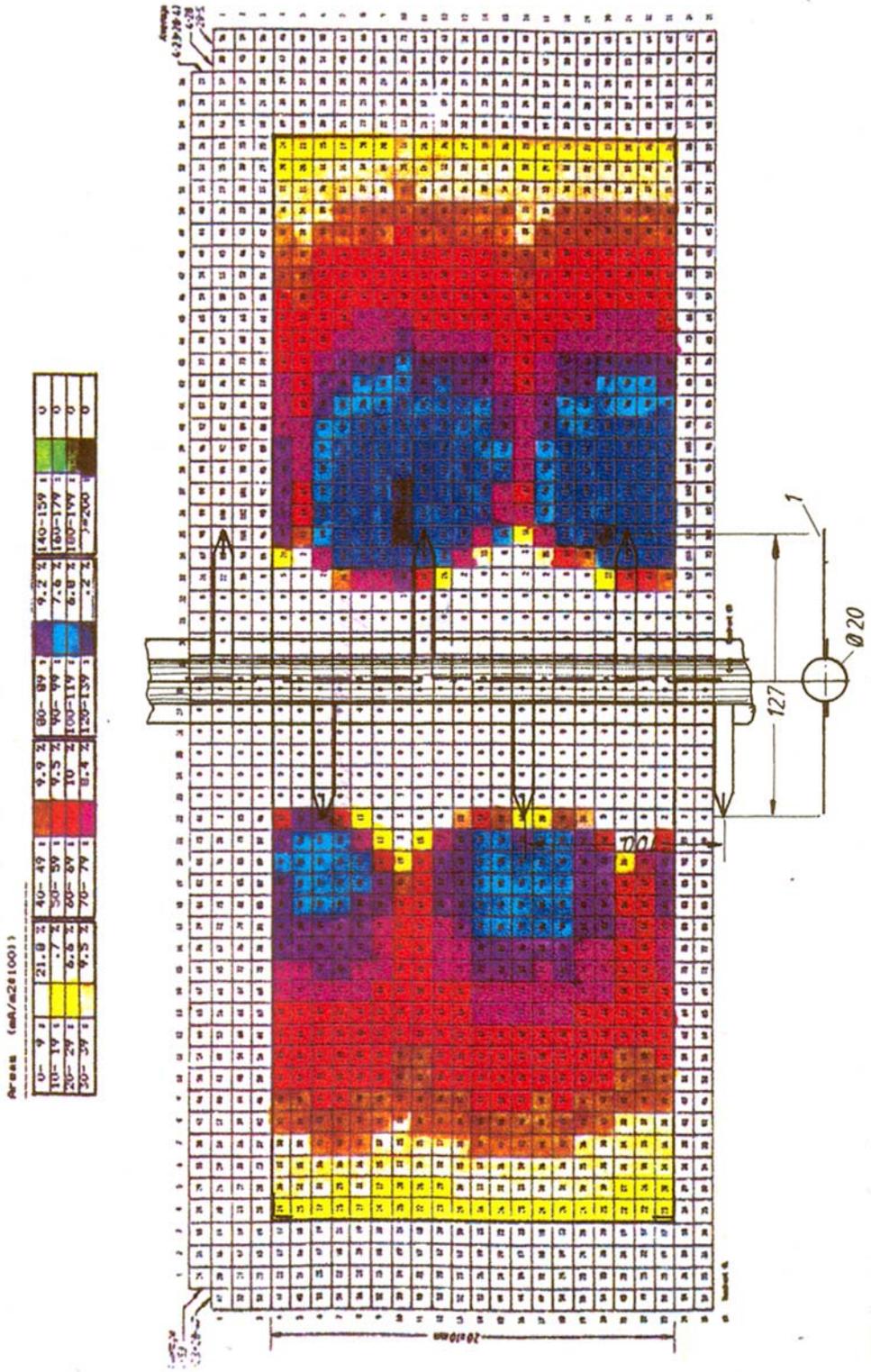
RDE's Tested in Lab



RDE	(MM)				RDE	(MM)			
	A	B	C	D		A	B	C	D
127 X 1	20	127	0	100	130x1	20	80	130	35
115 X 10	20	115	10	100					
130 X 1X	24	117	24	100					

FIGURE 4 – RDE'S TESTED IN LABORATORY

Figure 5 – RDE 127x1 Corona Current Dist.



RDE 115x10 (Figure 6) has a 20 mm (0.8 inch) diameter body, staggered emitters, a 115 mm (4.5 inch) total emitter span, and a 20 mm (0.8 inch) emitter tab spread. By spreading the emitter tabs, more corona current was steered in towards the RDE's body. The corona current distribution has a variance coefficient of 63%, and 16% of the test plate receives negligible current flow. This RDE is in widespread use in ESPs in the United States and overseas.

RDE 117x24 (Figure 7) has a 20 mm (0.8 inch) diameter body, staggered emitters, a 117 mm (4.6 inch) total emitter span, and a 24 mm (1 inch) emitter tab spread. By further spreading the emitter tabs, significantly more corona current was steered in towards the RDE's body. This RDE's corona current distribution has a variance coefficient of 59%, and only 11% of the test plate receives negligible current flow. This RDE is also in widespread use in the United States and overseas.

For comparative purposes, a non-aggressive type RDE was tested. RDE 130x1 (Figure 8) has a 20 mm (0.8 inch) by 80 mm (3.2 inch) body, opposed square-shaped emitters, a 130 mm (5.1 inch) total emitter span, and a 0 mm emitter tab spread. By increasing the size of the RDE's body and using straight emitter tabs, corona current was steered away from the RDE's body. This RDE's corona current distribution has a variance coefficient of 92%, and 37% of the test plate receives negligible current flow.

FIELD AIRLOAD DATA

The aggressive corona current generating capability of these special, customized RDEs, and their ability to produce varied current-voltage (V-I) relationships, is demonstrated in Figure 9. This figure compiles ESP startup airload data taken at ten commercial ESP installations. Pipe & Spike electrode data includes RDE body diameters of 38 mm (1.5 inch) and 51 mm (2 inch), and includes ESP gas passage widths varying from 280 mm (11 inches) up to 400 mm (16 inches). The customized RDE data includes ESP gas passage widths ranging from 280 mm (11 inches) up to 300 mm (12 inches).

Figure 7 – RDE 117x24 Corona Current Dist.

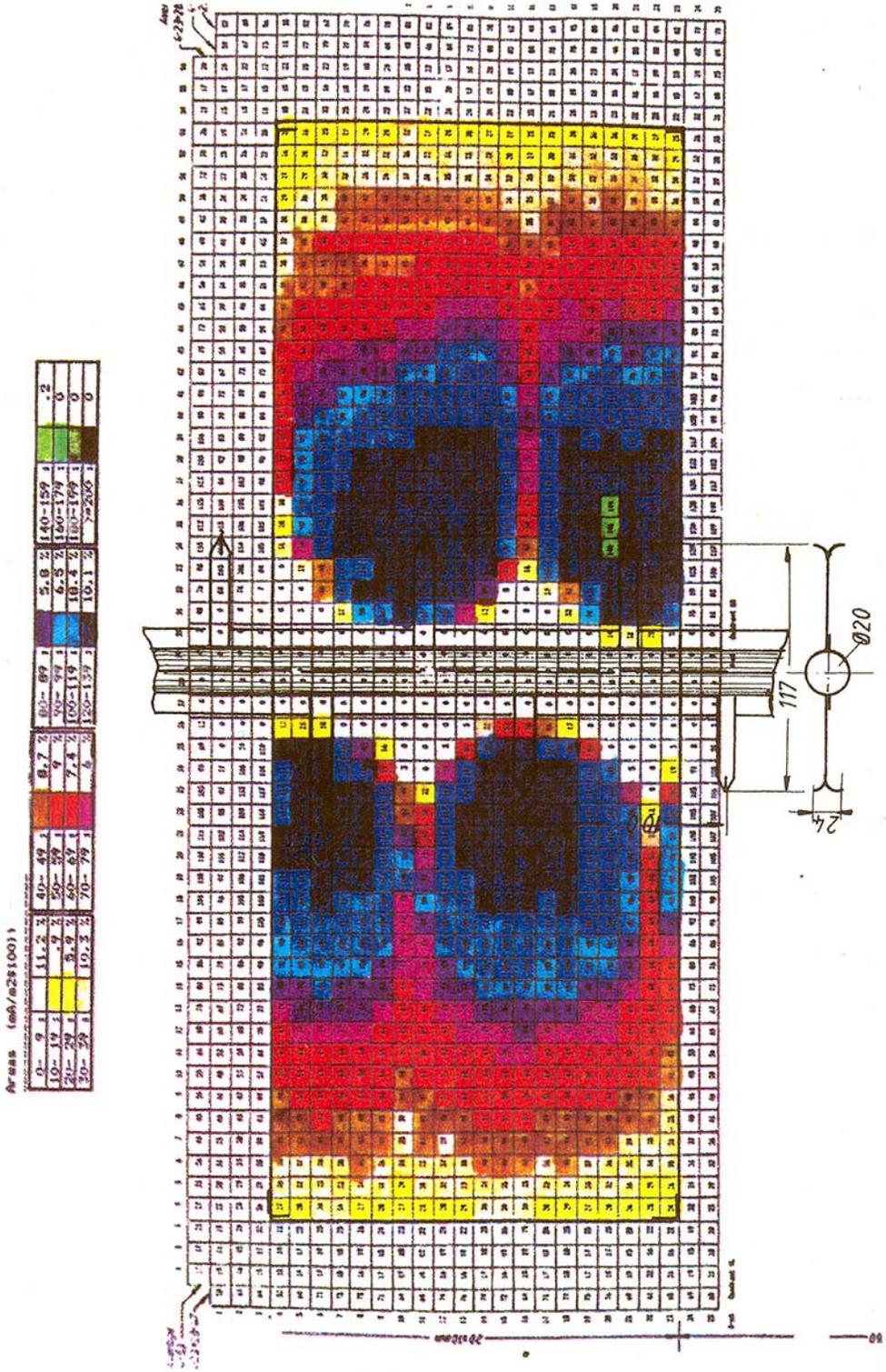
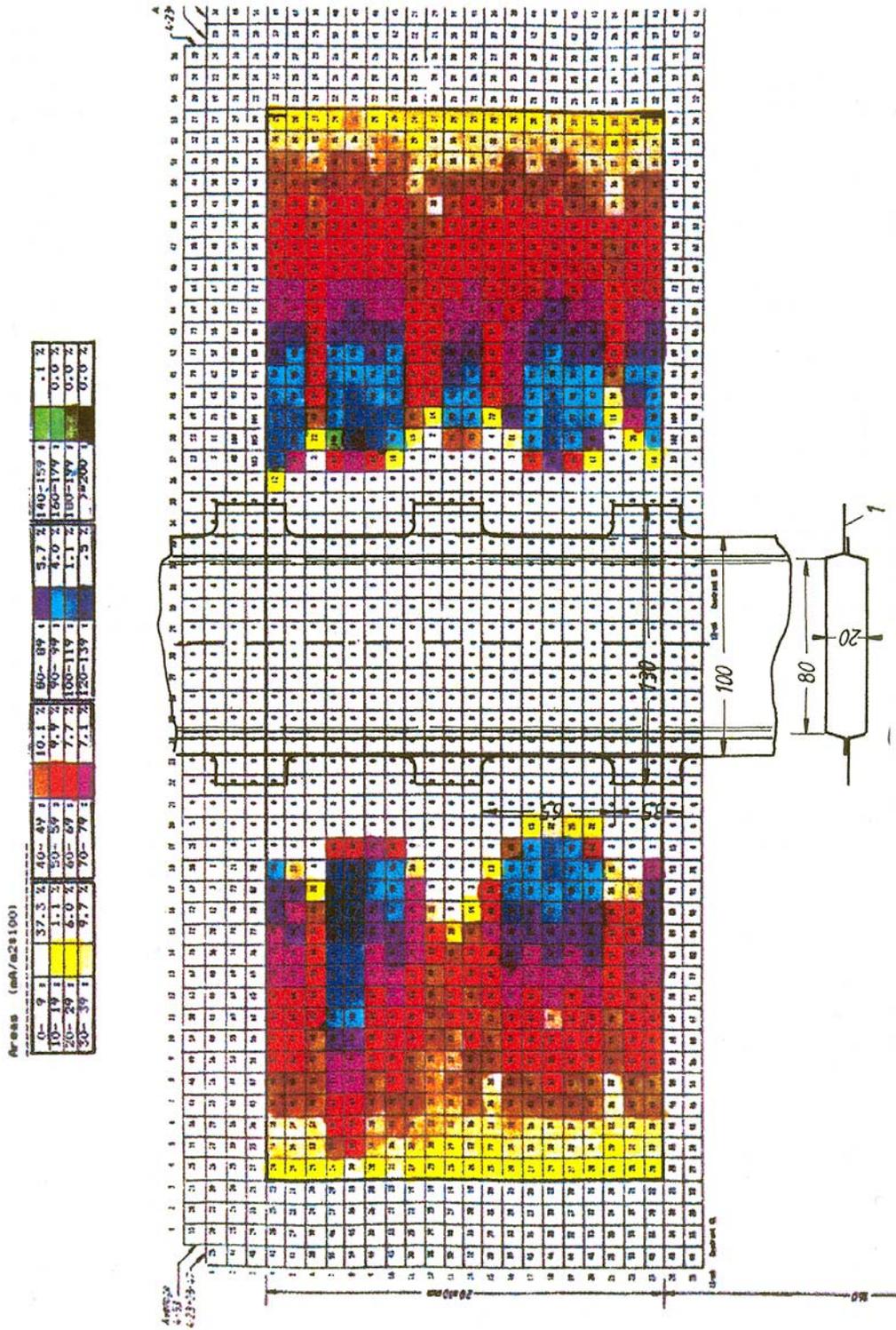


Figure 8 – RDE 130x1 Corona Current Dist.



RDE Airload

- RDE 1 – 114x12.7 SE
- RDE 2 – 114x17.5 SE
- RDE 3 – 114x25.4 SE
- RDE 4 – 114x25.4 OE

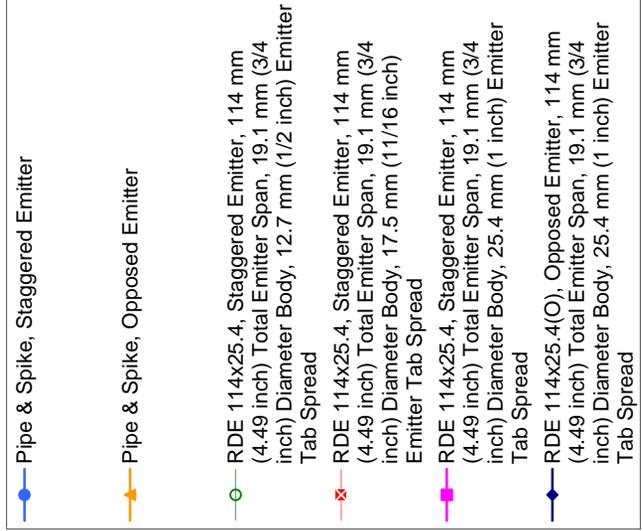
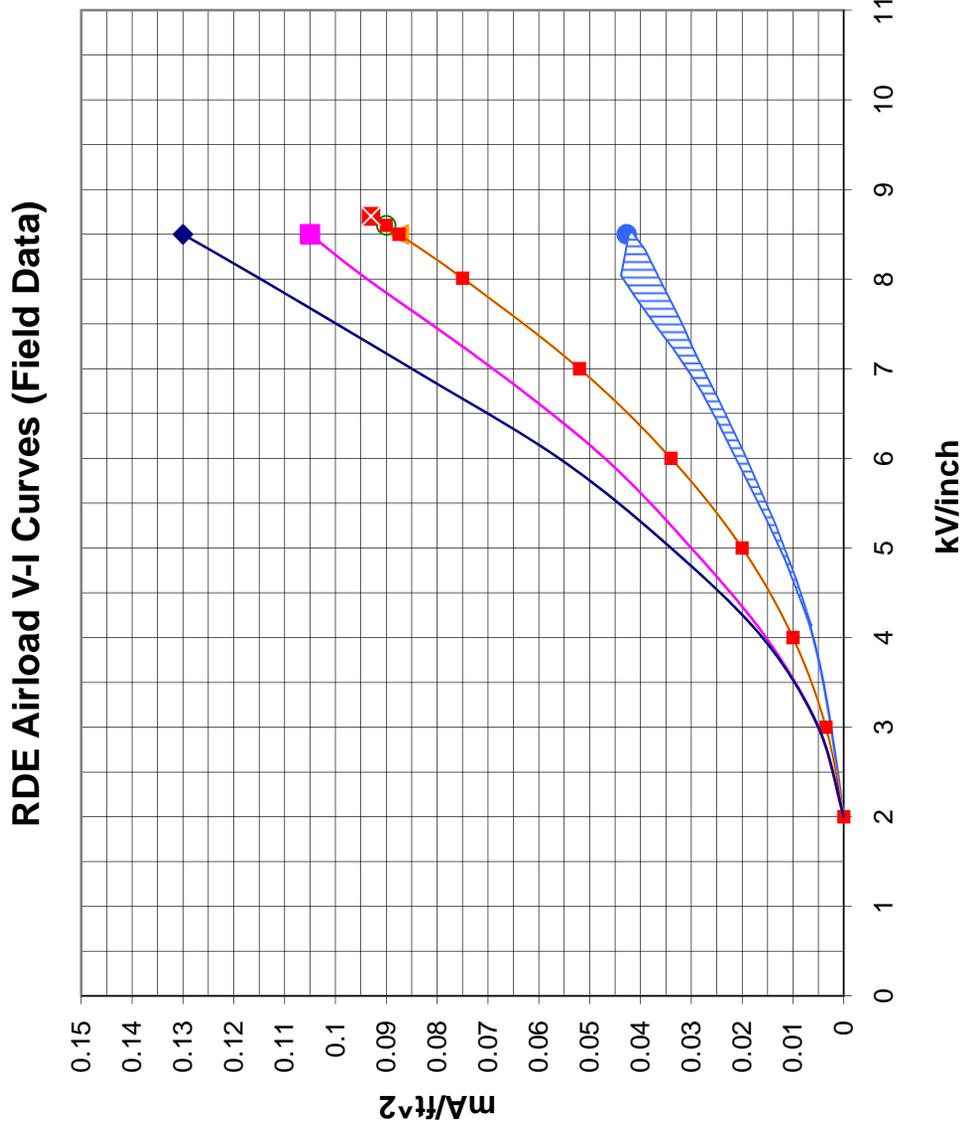


Figure 3

Comparing the airload V-I curves shown on Figure 9, four general conclusions may be drawn as listed below:

1. At an electric field strength of 3.35 kV/cm (8.5 kV/inch), the opposed emitter pipe & spike electrode produces approximately twice the corona current density produced by the staggered emitter pipe & spike electrode.
2. Customized RDEs with staggered emitters, and with emitter tab spreads of 13 mm (1/2 inch) and 18 mm (11/16 inch), produce near identical airload V-I curves as is produced by opposed emitter pipe & spike electrodes.
3. When the Customized RDE's emitter tab spread is increased from 18 mm (11/16 inch) to 25 mm (1 inch), corona current density increases by approximately 17% at an electric field strength of 8.5 kV/inch.
4. With opposed emitters and a 25 mm (1 inch) emitter tab spread, the Customized RDE produces approximately 44% more corona current density at an electric field strength of 3.35 kV/cm (8.5 kV/inch) than does the opposed emitter pipe & spike electrode.

FIELD OPERATING DATA

There are presently six recovery boiler ESPs operating with customized RDEs, as described on Table 1.

At two sites, designated Sites A and C on Table 1, side-by-side ESPs were provided with different RDE arrangements; one ESP utilizing conventional aggressive, current distributing RDEs and the other ESP utilizing Customized RDEs. It is unfortunate that at Site A the two ESPs' aspect ratio, treatment time and degree of sectionalization are significantly different, and so direct comparisons for purposes of evaluating RDE performance are meaningless at this particular site.

However, the side-by-side ESPs at Site C are physically identical with the sole exception of their RDE configurations, and so it was at first believed that a meaningful data comparison could be made. One such analysis, conducted in September 1998, is presented in Figure 10. This figure demonstrates enhanced current flow and fine particle charging in the first two fields (designated #1 TR and #2 TR) of ESP C2, with beneficial residual effects carrying into the downstream fields. The voltage-promoting effects of the ¼"-staggered RDEs in the last two fields (#5 TR and #6 TR) of ESP C2 are clearly evident, although the last field is constrained by the TR set's secondary voltage limit. ESP C2 demonstrated a 52.3% increase in overall corona power when compared to ESP C1. It was subsequently discovered during performance testing that there were significant flue gas volume flow rate and particulate loading differences between ESP C1 and ESP C2. In December, 1999, after the first two fields of ESP C1 were retrofitted with 1"-opposed RDEs, a direct comparison was finally made possible. An analysis conducted in March 2000 is summarized in Figure 11. ESP C1 demonstrated a 15.7% increase in overall corona power when compared to ESP C1 data recorded prior to December 1999, with all of this power increase realized in downstream fields.

FUTURE WORK

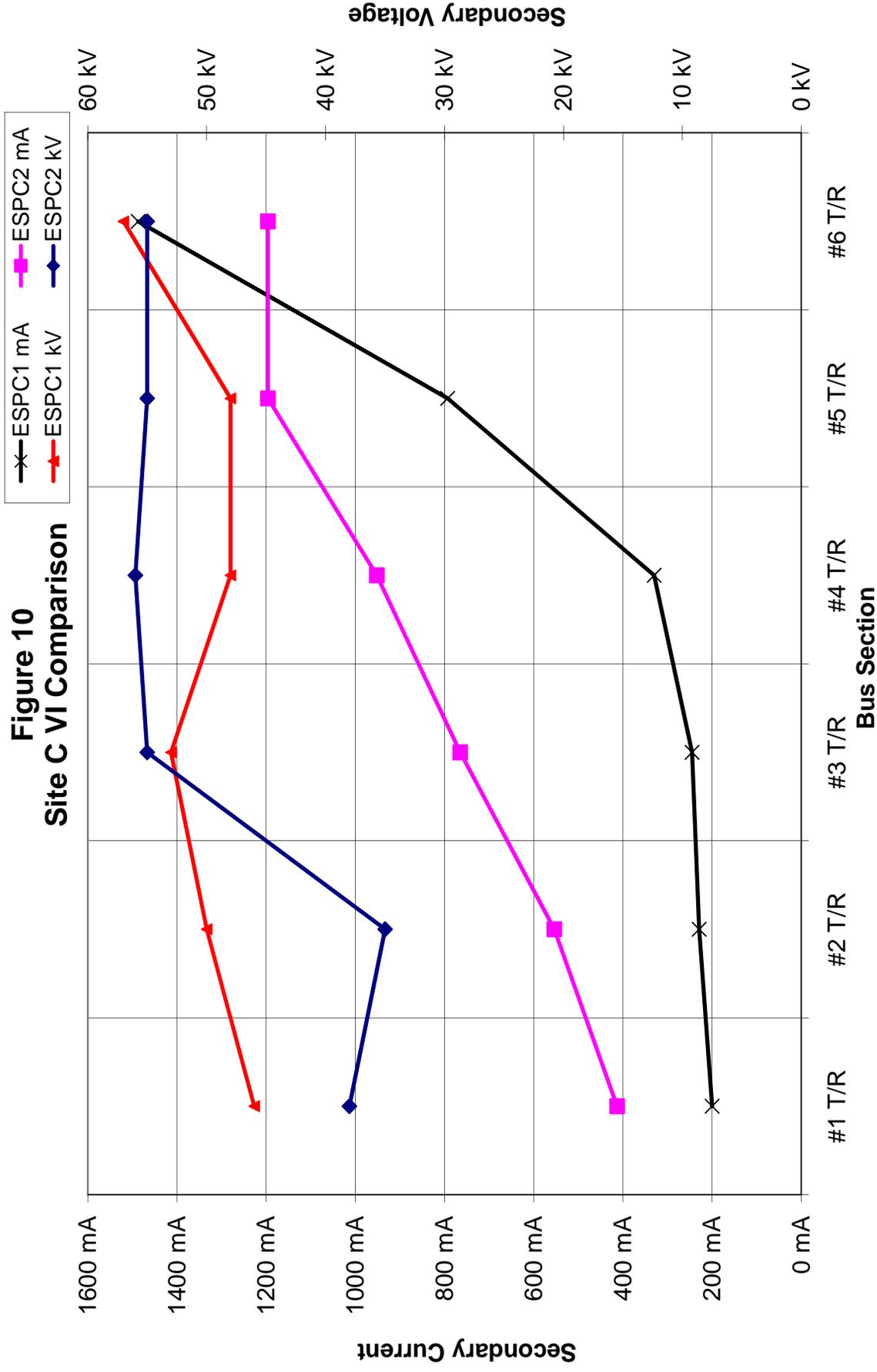
The configuration of Customized RDEs required for optimum recovery boiler ESP performance is currently a subject of on-going review and experimentation. Future investigations will focus on optimization of Customized RDEs for use in the ESP's downstream fields.

CONCLUSIONS

When a current distributing electrode is utilized, corona current hot spots and cold spots are not completely avoided but rather minimized, resulting in improved precipitation. When Customized RDEs are employed, the electrodes' corona current/voltage characteristics are biased from field to field, resulting in enhanced ESP performance.

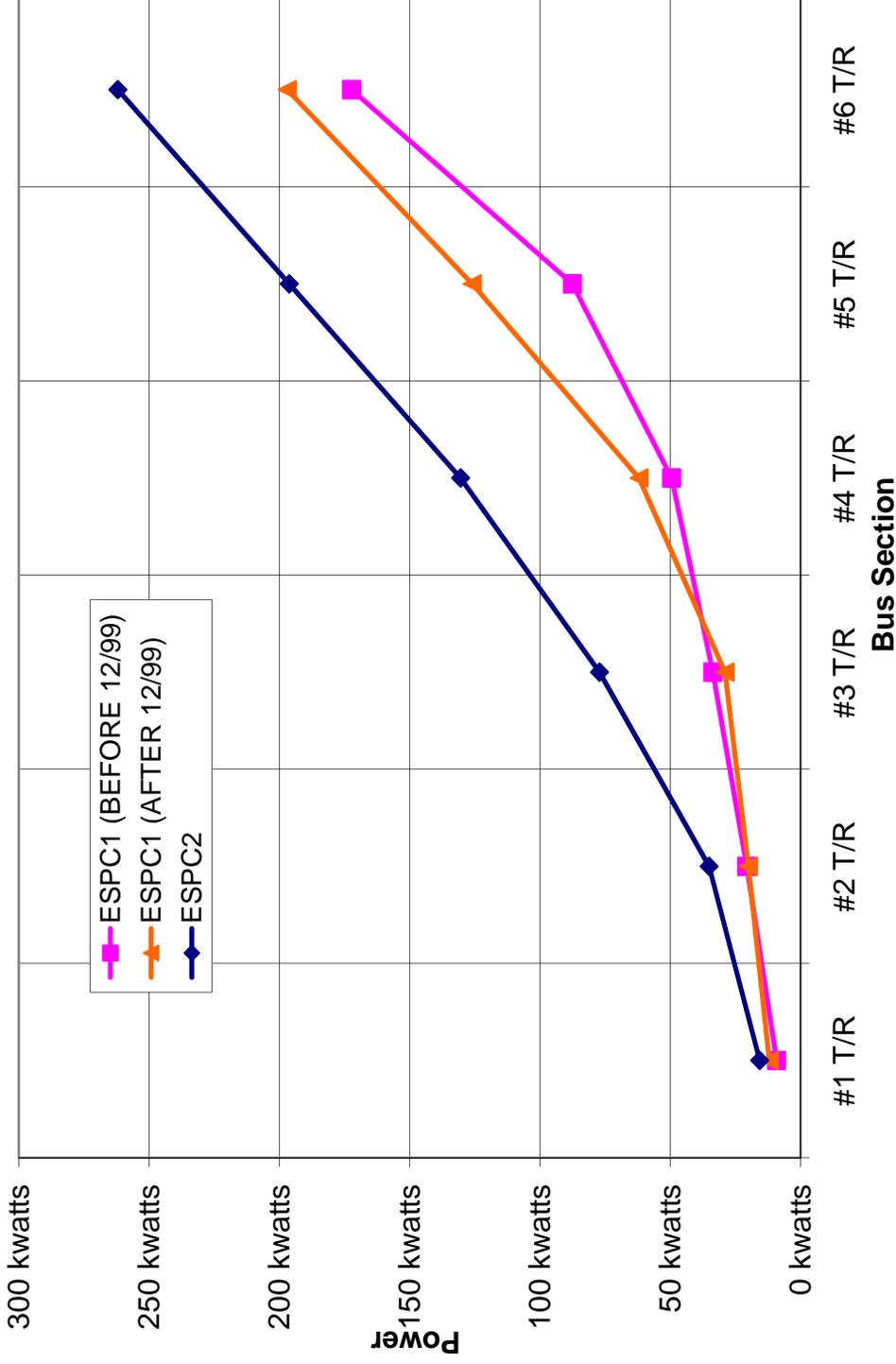
Side-by-Side ESPs at Site C

Figure 10
Site C VI Comparison



Direct Comparison of site C ESP's after Fields 1 & 2 of C1 Retrofitted with 25mm Opposed Emitter Electrodes

Figure 11
Site C Cumulative Power Comparison



Laboratory data and field airload data presented herein demonstrates that the corona discharge from Customized RDEs may be characterized as having: (1) a uniform corona current density on the surface of the collecting electrode plate; (2) an aggressive corona current discharge; and (3) the capability to significantly alter the RDE's V-I curve shape by either increasing or decreasing the RDE's emitter population and/or emitter tab spread.

Field operating data also demonstrates the capability to alter the RDE's V-I curve shape by either increasing or decreasing the RDE's emitter population and/or emitter tab spread. One recovery boiler ESP demonstrated a 15.7% increase in overall corona power through use of customized RDEs, when compared to conventional aggressive, current distributing RDEs.

REFERENCES

1. ELEX AG, "Discharge Electrodes Current Distribution and Consumption," Internal R&D Report, April 16, 1984.
2. Grieco, Gary J., "Electrostatic Precipitator Discharge Electrode Geometry and Collecting Plate Spacing - Selection Considerations," Power Gen '94 Conference, Orlando, Florida, December 7, 1994.
3. Southern Environmental, Inc., "Site C Voltage-Current Comparison," Internal Report, September 18, 1998.
4. Southern Environmental, Inc., "Site C RDE Investigation," Internal Report, March 30, 2000.

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