

# Improving Electrostatic Separation in Processing Plant

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## ABSTRACT

Electrostatic separation has been a mainstay of minerals sands flowsheets for over 50 years. Recent electrostatic developments by Outokumpu Technology- Physical Separation Division have shown better conductor / non-conductor separation than technology previously available. Results to date show significantly increased separation efficiency over prior-art high-tension roll electrostatic separator (HTR). These improvements allow greater simplification of MSP circuits by minimizing re-circulating loads. The distinct features of the *eForce* include: 1). A provision that minimizes the affects of particle size to improve separator performance, 2). an enhancement of the design and arrangement of the static electrode providing a greater attraction force for separating fine conductive particles, and 3). inner roll and outer plate electrode configuration to improve separation efficiency and throughput capacity.

### Key Words

*eForce*, Electrostatic, Ion bombardment, HTR, Separation Efficiency, Electrostatic Classifier

## INTRODUCTION

Over the last 50+ years, the Physical Separation Division of Outokumpu Technology and its predecessors have conducted numerous studies to improve the efficiency of processing circuits for mineral sands and other industrial minerals producers, worldwide. These studies have involved both wet and dry processes, resulting in improved operations as well as the development of new physical separation process equipment, such as the *eForce*. The *eForce* combines the best attributes of both roll and plate separators into one machine.

The data presented is derived from a mineral sands plant that integrated the *eForce* electrostatic separator into both conductor-rich and non-conductor-rich streams.

## BACKGROUND

Electrostatic separation of minerals based on the differences in conductivity is a mature technology. High-tension roll separators have been widely used in the minerals industry since the 1960's. Their greatest use is separating minerals found in heavy sands from beach or stream placers (Dance and Morrison, 1992).

The fundamental difference in electrostatic separator design lies in the use of either a pure electrostatic field or a convective field. In addition, these separators may be roughly classified under their general method of conveying granular material through the electrostatic fields: (1) stationary chutes, plates, or shelves, (2) rotary roll, (3) free falling stream, and (4) vibrating tables (Ralston, 1961). Both roll and plate versions are used extensively in the mineral sand processing industries.

High-tension electrostatic separators utilize the electrical conductivity difference between the various minerals within an ore feed. As shown in Figure 1, the high-tension roll electrostatic separator (HTR) utilizes a grounded roll to transport feed material through the high voltage ionizing field (corona) where particles are charged by ion bombardment. Conducting particles pass their charge to the grounded carrier electrode (roll) and are therefore free to be thrown from the roll by centrifugal and gravity forces. Non-conducting particles are pinned to the carrier electrode and are transported further around the roll periphery, where they drop from the electrode surface, either because their charge dissipates, or by mechanical means, e.g. brush and high voltage AC wiper (Kelly and Spottiswood, 1989).

The high-tension electrostatic plate separator (HTP) is comprised of a curved, inclined, electrically grounded plate, onto which a feed mixture is introduced, and where particles will travel over and down the surface due to gravity. As shown in Figure 2, conductive particles obtain surface charge by induction when subjected to the electric field created between the static and grounded electrodes, while the non-conductive particles remain uncharged. The electrical attraction of the static electrode lifts charged conductors from the grounded plate, thus separating them from the non-conductive particles. They then discharge at a different trajectory resulting in mineral separation.

Operating parameters that affect separation performance in an HTR machine include:

1. roll speed,
2. number of corona electrodes and electrode position with respect to the grounded electrode,
3. intensity and polarity of applied potential,
4. feed rate,
5. electrode surface cleaning, and
6. temperature of the feed material
7. mineral surface condition

Throughput capacity of a high tension electrostatic separator is closely related to the roll speed, roll width, and characteristics of the feed material. For a roll with a smaller diameter, a higher rotation speed is required in order to maintain a substantial feed rate. However, at higher RPM, coarse, non-conductive particles tend to leave the roll surface too early due to the increase in centrifugal force resulting in a large portion of misplaced non-conductive particles in the conductor stream. Vice versa, under a low RPM condition, fine conductive particles do not gain enough inertia to be thrown off the roll, resulting in misplacement of the nonconductor stream. Therefore, for the treatment of particle mixtures with a range of physical characteristics, including conductivity, particle size, and density, it is necessary to adjust the roll speed and electrode positions to optimize the process.

One of the earliest commercial forms of electrostatic separators utilized a sloping plate. These separators were constructed of thin sheet metal plates, either straight or curved, that were positioned in a sloping fashion to allow free flow of granular material under an active electric field. Under the influence of an electrostatic field, conductive particles, especially fine grains, were lifted towards the charged electrode, while the coarse non-conducting particles were effectively rejected. This is the converse of the separation in a high-tension roll separator, where most of the effective separation is of fine non-conductors from coarse conductors. Therefore, a combination of high tension roll separators, as primary roughers, followed by final cleaning using plate type separators is employed in many mineral sand processing flowsheets (Wills, 1992).

#### **DEVELOPMENT GUIDELINES OF THE *eForce* ELECTROSTATIC SEPARATOR**

Particle charging, feed size distribution, and centrifugal force have a great impact on the separation efficiency of a high-tension roll electrostatic separator. The larger the surface area of a particle, the more surface charge it obtains in a discharging electric (corona) field. The specific surface area of a fine particle is larger than that of a coarse one; therefore, greater charge is acquired. As shown in Equation (1), when the particle size increases, the centrifugal force,  $F_C$ , acting on the particle increases rapidly because  $F_C$  is proportional to the cube of the particle radius,  $r$ ,

$$F_C = \frac{4\pi}{3} r^3 \rho \omega^2 R \quad [1]$$

where  $\rho$  is specific gravity of particles,  $\omega$  the angular velocity of the roll and  $R$  is the radius of the roll. Coarse particles, characteristically, have small specific charges and large centrifugal forces. Therefore, for the separation of coarse particles, if they are not sufficiently charged, the non-conducting particles may leave the roll electrode surface early and become misplaced with conducting product. To prevent this, the electrode arrangement used to separate coarse particles should provide a wider corona field to enhance particle charging. In addition, the roll rotation speed should be lowered in order to minimize the negative effect from the centrifugal force. For fine particle separation with an HTR, the conducting particles may

remain on the roll surface too long; hence, they are misplaced with non-conducting product. The misplacement can be attributed to 1). higher surface charge, less inertia/centrifugal forces, and 2). particle entrapment as shown in Figure 3. Therefore, the electrode arrangement used to separate fine particles should provide a narrower corona field, less corona current and a wider and stronger static field. In addition, higher roll rotation speed should be used to ensure the fine conducting particles leave the electrode surface as early as possible. From a processing point of view, for a feed material with wide particle size distribution, it is beneficial to split the feed material into narrow size fractions in order to obtain higher separation efficiency.

To better understand the static field intensity of a high-tension electrostatic separator, see the analytical model (Mesenyashin, 1997) shown in Figure. 4. Figure 5a shows the calculated static field intensity based on the equations above. Overlapping this calculation results into a roll and static electrode configuration, a schematic of which is shown in Figure 5b. It can be noted that for a single static electrode configuration, the highest field intensity is at the centerline, from the center of roll to the center of static electrode. The results also show that away from the static electrode, the field gradient decreases rapidly. For fine particle separation, where a stronger and wider static field is required, this configuration imposes an undesirable effect. Figure 6 shows the static field intensity distribution with a multiple static electrode arrangement. It can be seen that the field intensity pattern is stronger and wider within the separation zone for this type of arrangement. Stronger field intensity may also help to prevent the coarse non-conducting particles from leaving the roll surface too early because the static electrodes serve as a repelling force.

In general, to achieve effective separation using a high-tension electrostatic separator, the applicable particle size is coarser than approximately 100 $\mu\text{m}$ . In practice, uniform particle size feed leads to better separation efficiency. Therefore, effective sizing of the feed material should be addressed in high-tension electrostatic separation in order to render high separator performance. Sizing of material has been applied extensively in the processing industry. Screening is used on relatively coarse material as its efficiency decreases rapidly with fineness. Classification is the standard for sizing of particles finer than 250  $\mu\text{m}$ . In an electrostatic separator, the sizing mechanism is the influence of the electric field on particle acceleration. . Particles acquire surface charge when they are subjected to ion bombardment as shown in Figure. 7. The physical law governing particle acceleration,  $a$ , in an electric field is given as

$$F_E = qE \quad [2]$$

$$a = \frac{F_E}{m} = \frac{qE}{m} = \frac{3}{4} \frac{qE}{\pi r^3 \rho} \quad [3]$$

where  $F_E$  is the electric force,  $q$  is particle's charge,  $E$  is the electric field intensity,  $m$  is particle's mass,  $r$  is the radius of the particle, and  $\rho$  is the specific gravity of the particle. Equation (3) suggests that the acceleration of fine, charged particles in an electric field is greater than that of coarse particles. Under cross flow condition, i.e. particles are falling in vertical direction while corona ionization is generated in horizontal direction, the net effect of gravitational force and electrical force on the free falling trajectory of particles is greatly enhanced. In the other words, fine particles drift in the x-axis direction under the influence of electrical force while gravitational force dominates the free fall trajectory of coarse particles, thus, particle sizing can be achieved.

Based on the analytical model and engineering data, a pilot scale *eForce* electrostatic separator has been developed as shown in Figure 8.

## RESULTS AND DISCUSSION

### Case Study I: Conductor-Rich Feed Stream

For performance evaluation, plant test work on a pilot-scale *eForce* electrostatic separator was conducted at an Iluka, Green Cove Springs, Florida, USA, operation. The separator was designated to reduce the CaO content in the feed to the leucoxene stream by removing epidote so that the leucoxene would meet product specification, i.e. less than 0.2 per cent CaO. As shown in Table I, the *eForce* reduced the CaO content in the feed from 0.41 to 0.08 per cent at a yield of 95 per cent while the HTR lowered the CaO

content from 0.41 to 0.18 per cent at a yield of 85 per cent. A comparative separator performance plot is given in Figure 9. It should be pointed out that HTR collected conductor-rich, middling, and nonconductor-rich streams while the eForce only collected conductor and non-conductor streams. Test results from this series of test work are given in Table I. As shown in Table I, the significant differences in the reject stream from the eForce and HTR suggests that the eForce is capable of removing fine conductor particles more effectively than the plant's existing high tension electrostatic separator. The improved separation efficiency can be attributed to 1). effective nondischarging static electrode arrangement that helps to pull fine conductor particles away from the roll surface, and 2). combined effects from the discharging and nondischarging electrodes of the eForce results in less middlings.

### **Case Study 2: Non Conductor-Rich Feed Stream**

An additional pilot test program was performed with non conductor-rich feed material on the eForce to evaluate the separator performance. A zircon scavenger feed stream at the same plant was subjected to the one-pass pilot scale e-Force unit at a feed rate of 110 kg/cm/hour per feed width. Test results showed that eForce achieved an 85 per cent yield in the zircon product while the HTR produced a 56 per cent yield at a similar metallurgical performance, i.e. 2 per cent TiO<sub>2</sub> contamination in the zircon product. Test results of this series of experimental work are given in Table II.

Table I

	Feed	eForce Conc.	HTR Conc.	eForce Tail	HTR Tail	HTR Mids
Yield (%)		95.47	84.80	4.53	15.20	
TiO <sub>2</sub>	65.61	66.80	66.48	46.39	61.07	66.66
ZrO <sub>2</sub>	0.09	0.05	0.05	1.14	0.42	0.08
SiO <sub>2</sub>	0.87	0.17	0.30	13.16	4.04	0.57
Al <sub>2</sub> O <sub>3</sub>	1.63	1.03	1.16	12.44	4.49	1.37
Fe <sub>2</sub> O <sub>3</sub>	26.42	26.91	26.87	27.00	26.03	26.03
CaO	0.41	0.08	0.18	5.87	1.79	0.26
MgO	0.21	0.02	0.16	0.38	0.18	0.19
P <sub>2</sub> O <sub>5</sub>	0.16	0.15	0.14	0.44	0.23	0.16

Table II

	<b>eForce</b>				<b>HTR</b>			
	TiO <sub>2</sub> (%)	Yield (%)	Cum. Yield (%)	Cum. TiO <sub>2</sub> (%)	TiO <sub>2</sub> (%)	Yield (%)	Cum. Yield (%)	Cum. TiO <sub>2</sub> (%)
Feed	5.37	100.00			5.37	100.00		
Conductor Stream	46.25	3.13	3.13	1.45	16.15	24.45	24.45	3.95
Middling Stream	20.88	12.40	15.53	4.04	5.02	19.43	43.88	4.92
non-Conductor Stream	1.81	84.47	100.00	5.57	1.01	56.12	100.00	5.49
	<b>eForce</b>				<b>HTR</b>			
	ZrO <sub>2</sub> (%)	Yield (%)	Cum. Yield (%)	Cum. ZrO <sub>2</sub> (%)	ZrO <sub>2</sub> (%)	Yield (%)	Cum. Yield (%)	Cum. ZrO <sub>2</sub> (%)
Feed	57.43	100.00			49.64	100.00		
Conductor Stream	24.43	3.13	3.13	0.76	49.64	24.45	24.45	12.14
Middling Stream	47.17	12.40	15.53	6.61	57.64	19.43	43.88	23.34
Non-Conductor Stream	59.82	84.47	100.00	57.14	60.42	56.12	100.00	57.24

## **CONCLUSIONS**

Outokumpu's eForce has made a significant difference to both TiO<sub>2</sub>-rich and zircon-rich feed. Performance improvement can be realized by using this improved electrostatic technology. Specifically:

- The *eForce* results showed dramatic improvements in separation efficiency over conventional HTR. For the leucoxene stream efficiencies increased from 76 per cent to 88 percent. For the zircon scavenger operation efficiencies increased from 74 per cent to 81 percent.
- For the zircon scavenger operation the e-Force produced an 85 per cent yield over the HTR's 56 percent yield while maintaining the same product quality of 2% TiO<sub>2</sub> in zircon product.
- The eForce cut recirculating loads from 44 per cent to 16 percent. The improvement in separation efficiencies and reduction in recirculating loads not only results in better grades and recoveries of valuable heavy minerals but also promote more stable processing and, consequently, reduced operating costs.

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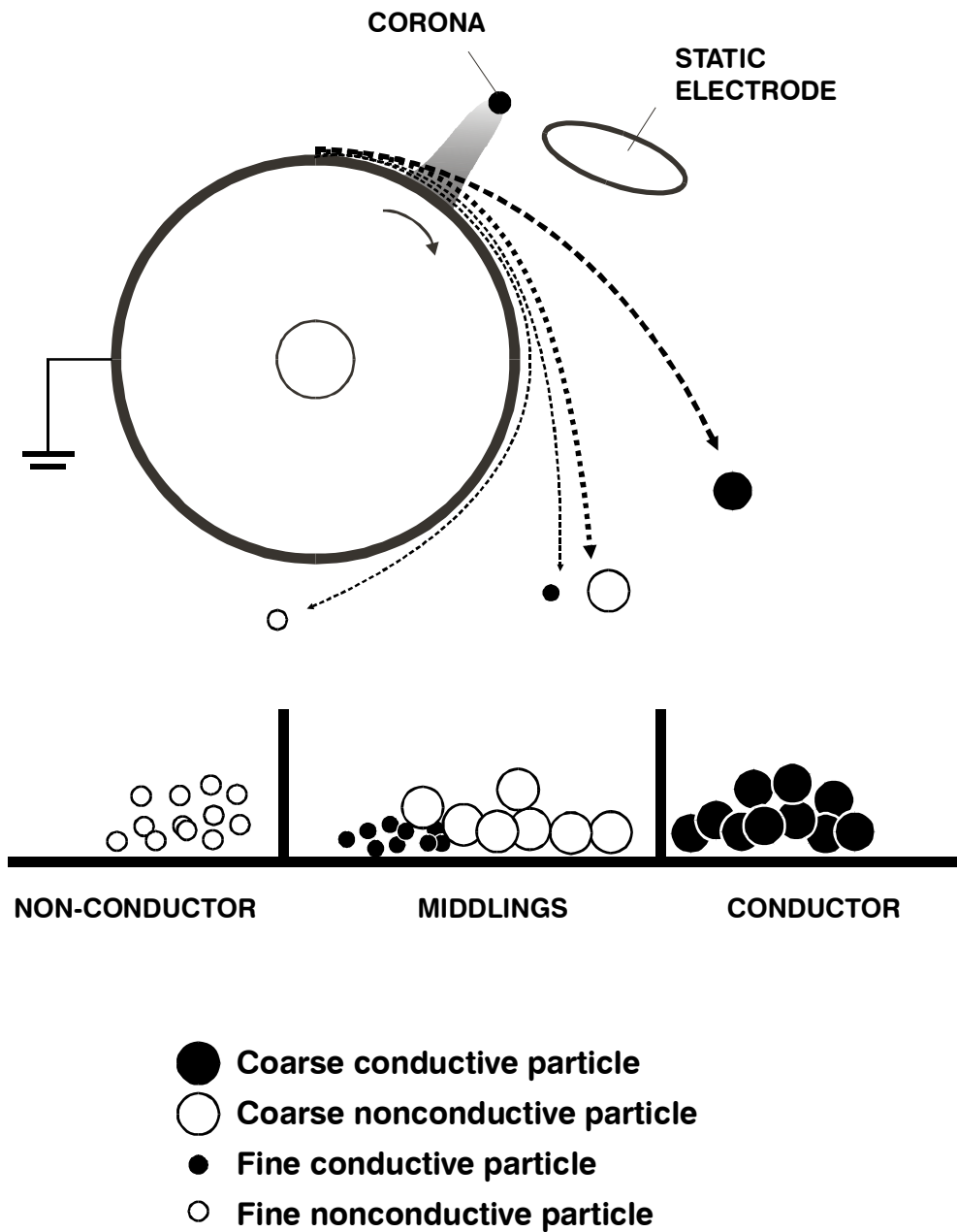


Figure 1 Principle of the high-tension roll electrostatic separator used for conductor and non-conductor separation.

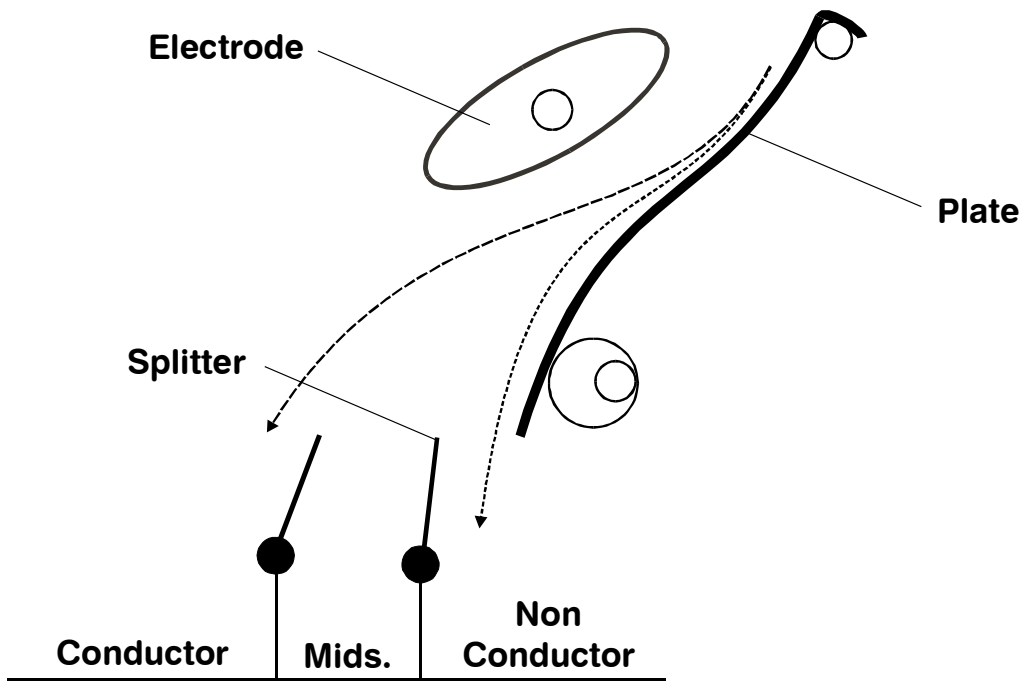


Figure 2 Schematic illustration of a plate type electrostatic plate separator.

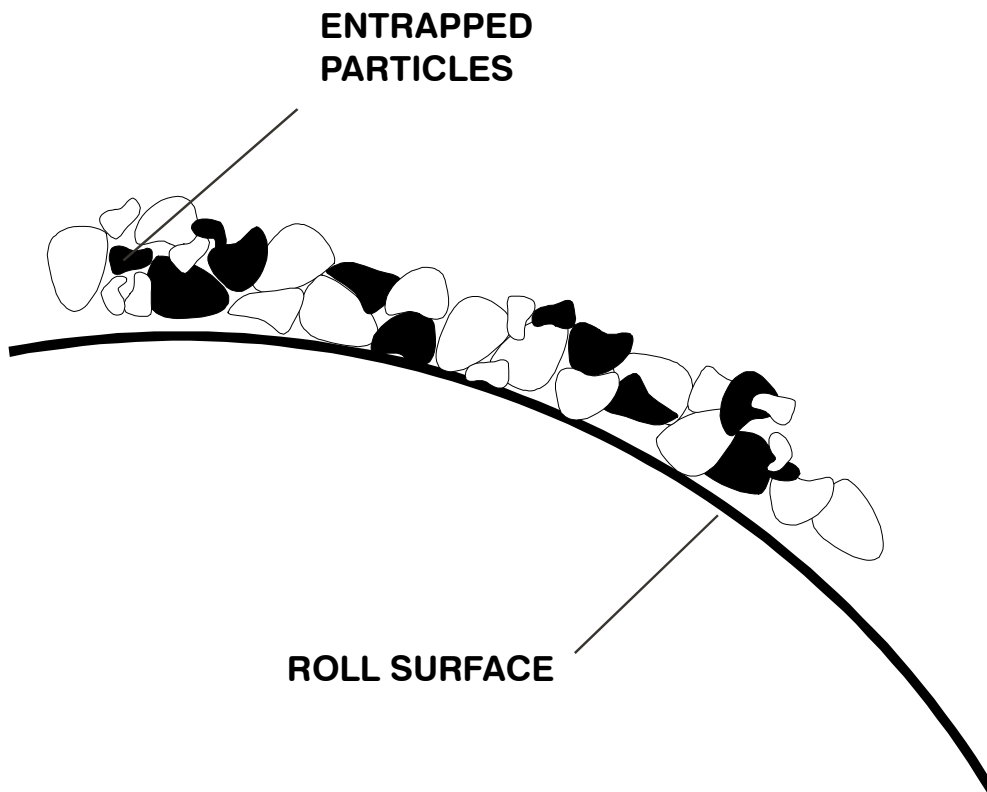


Figure 3 A schematic representation of particle entrapment in a layer of feed particles.

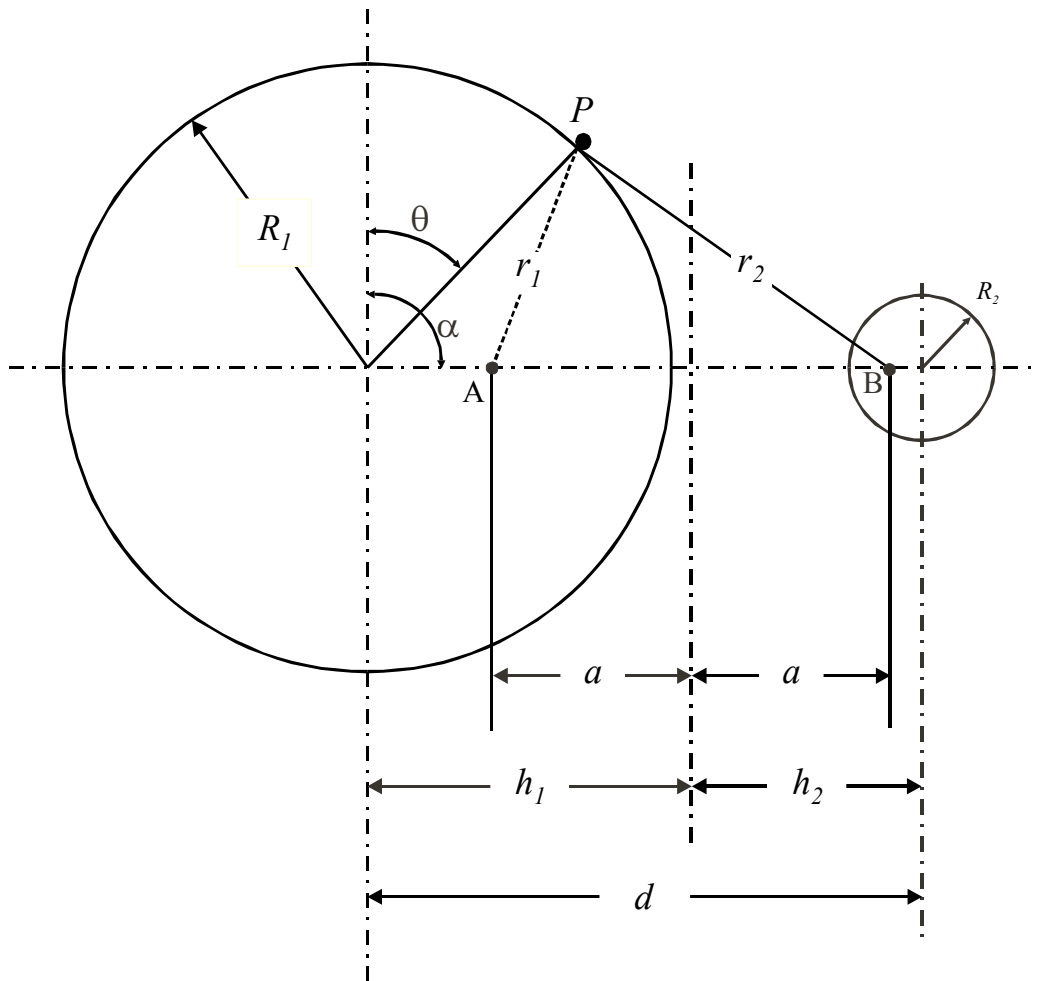


Figure 4 The electrical axis model used to calculate the static field intensity in a high-tension electrostatic separator.

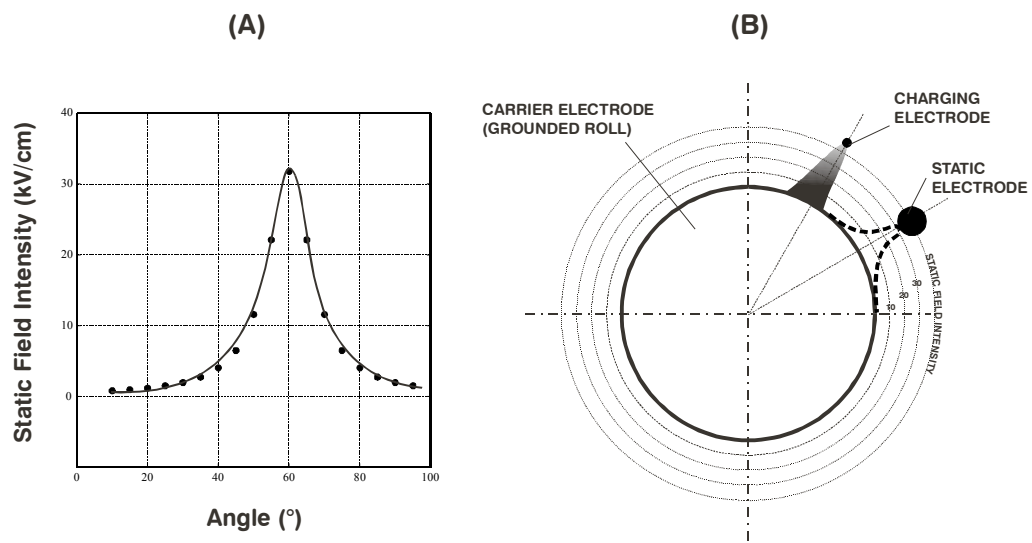


Figure 5 Calculated static field intensity distribution for a single static electrode arrangement based on the electrical axes model.

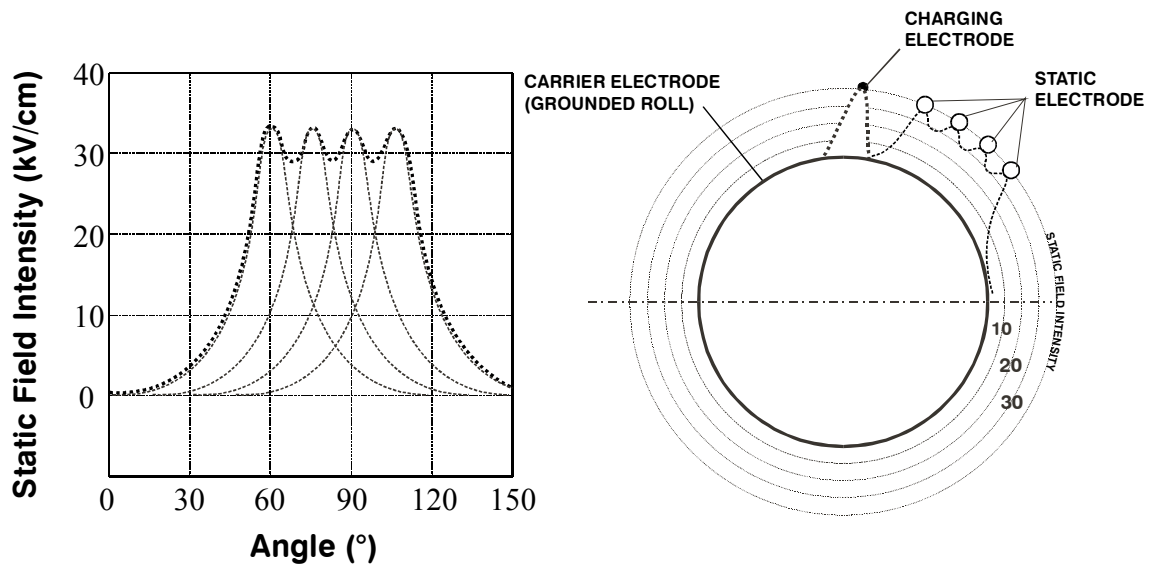


Figure 6 *eForce* static field intensity

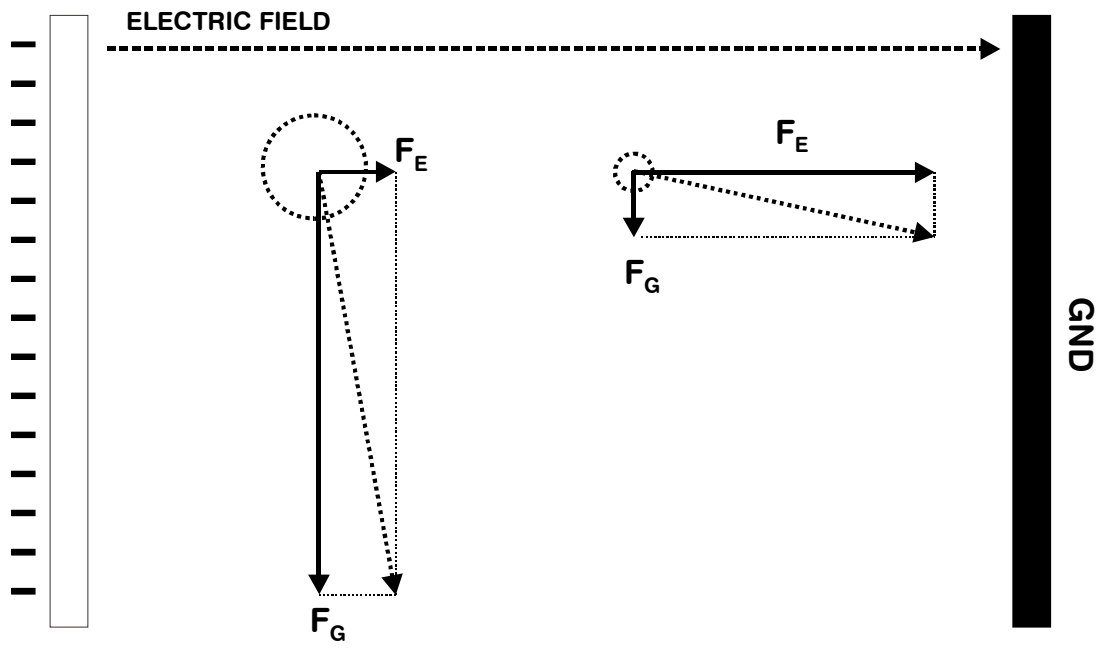


Figure 7 Interplay between electric and gravity forces

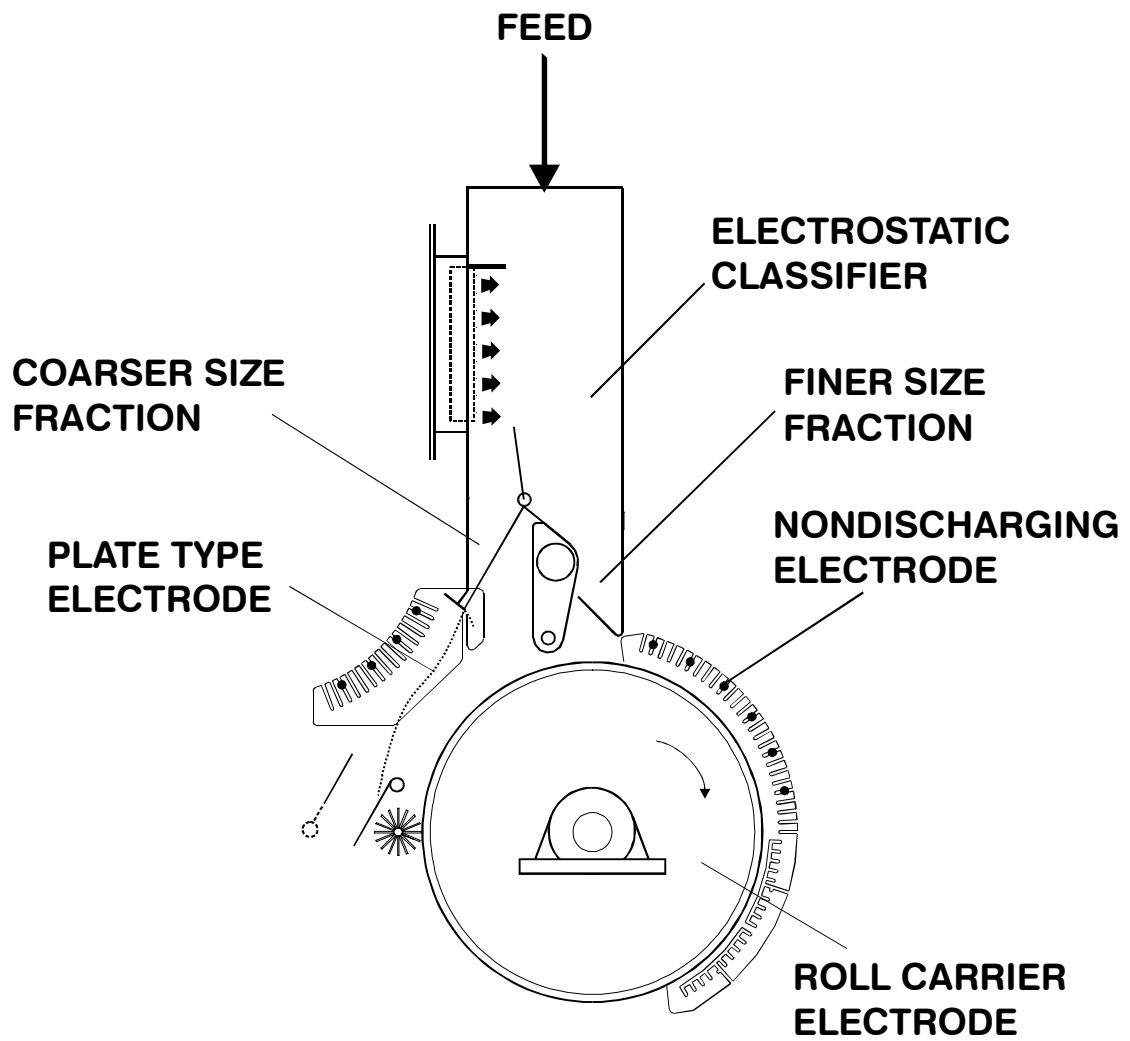


Figure 8 Schematic cross section of the *eForce* (Patent pending)

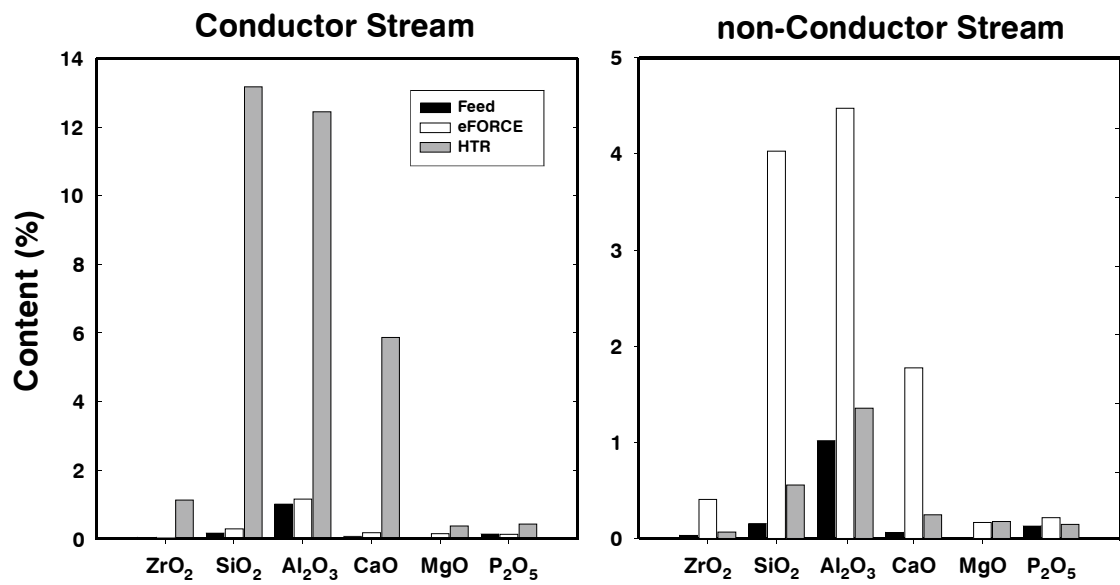


Figure 9 Comparison of product quality from tested streams for *eForce* and HTR