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A NEW TYPE OF CORONA ELECTRODE FOR HIGH - TENSION SEPARATORS

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ABSTRACT

The corona discharge represents the main physical mechanism involved in the charging of granular materials in high-tension separators. This is why an attempt has been made to formulate several criteria for choosing the most adequate electrode. A crude evaluation of the required corona current for an efficient charging has been considered as a necessary starting point for a well-grounded decision on the type of electrode to be employed with a certain application. The specific features of several models of corona electrodes are briefly discussed, in order to justify the need for a new design. The original corona electrode proposed by the authors is characterized by lower corona on-set voltage, better stability of the corona discharge during long-time operation, and shorter maintenance time, as compared to "classical" solutions. Systematic experiments made on a laboratory model of this electrode enable several design considerations that could be easily extended to other similar devices. Two industrial high-tension separators are already provided with the new type of electrode.

INTRODUCTION

The term "high-tension separator" is usually employed to name an important category of electrostatic devices which achieve the selective sorting of mixed granular materials [1], [2], [3]. They differ from other types of electrostatic separators [4] by the fact that the corona discharge, produced by one or several high-voltage electrodes, represents the main physical mechanism involved in the charging of the granules [5], [6].

There has been demonstrated by Tonoya and Nakamura, cited in [7], that corona charging is ten-fold more efficient than triboelectrification. This justifies the extended industrial utilisation of high-tension separators [8], [9], [10] and the continuous efforts to improve the performances of their corona electrodes [11].

The aim of this paper is to suggest several criteria for evaluating the electrodes chosen for a certain application. At the same time, it presents the specific features of a new electrode design.

CRUDE EVALUATION OF REQUIRED CORONA CURRENT

In most high tension separators, the corona discharge is produced between an "active" electrode, energized by a high-voltage supply, and a rotating roll electrode, connected to the ground [12] (Fig. 1).

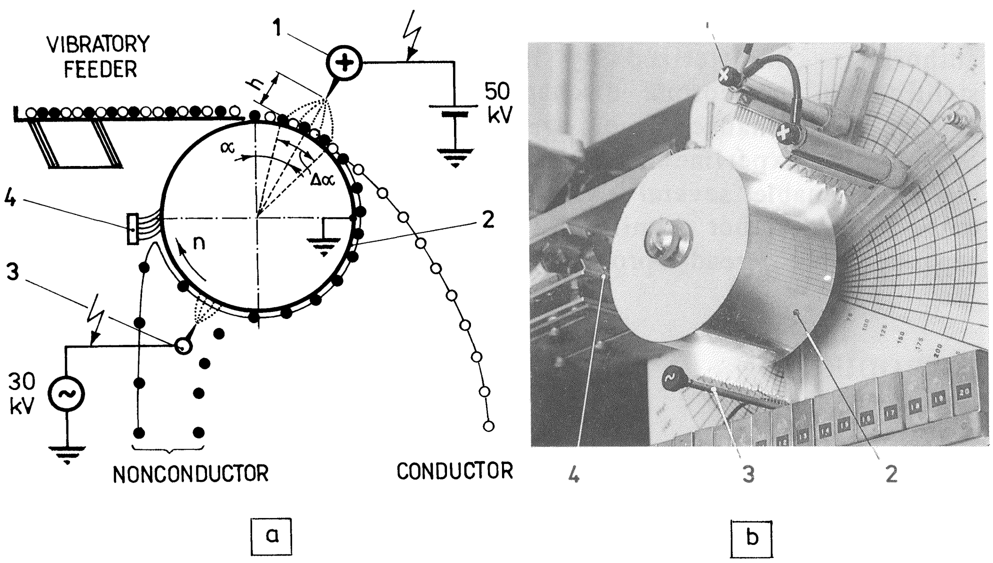


Fig. 1. Roll-type high-tension separator: a - principle of operation (two high-voltage supplies); b - space-charge zones generated by the active and neutralizing electrodes; 1 - active corona electrode; 2 - grounded rotating roll electrode; 3 - charge neutralization

The material to be separated is introduced into the electric field zone by the roll electrode, the velocity of which (n) is continuously-adjustable up to several hundreds of rotations per minute. Let $\Delta\alpha$ be the angular extension of the corona discharge. The duration of particle passing-through the high-intensity electric field zone is:

$$t_c = \Delta\alpha/(2.\pi.n) \ . \qquad (1)$$

The charge Q acquired by a particle in a uniform mono-ionised electric field E varies with time as:

$$dQ/dt = (Q_m - Q)^2/(Q_m.\tau) \ , \qquad (2)$$

where:

$$\tau = 4.\varepsilon/(k.q), \qquad (3)$$

ε – electric permittivity,

k - mobility of the ions,

q - space charge density,

Q_m - maximum electric charge [13].

In order to charge the particle to saturation, t_c should be at least five times greater than τ:

$$\Delta\alpha/(2.\pi.n) > 5.[4.\varepsilon/(k.q)] \qquad (4)$$

or:

$$q > 40.\pi.\varepsilon.n/(k.\Delta\alpha) \ . \qquad (5)$$

Thus, the required density of the corona current is:

$$J = q.k.E > 40.\pi.\varepsilon.n.E/\Delta\alpha \ . \qquad (6)$$

If U is the potential of the active electrode and h represents the distance between the corona element and the roll electrode, then J can be approximated as:

$$J > (40.\pi.\varepsilon.n/\Delta\alpha).(U/h) \ . \qquad (7)$$

The corona current produced by the wire electrode distributes itself on the surface of the grounded electrode in a zone not larger than $h.\sqrt{3}$ [14]. This is why J can be expressed, in a first approximation, as:

$$J = i/(h.\sqrt{3}), \qquad (8)$$

where i is the corona current per unit of length.

An efficient corona charging requires a current per unit of length exeeding the minimum value given by (7) and (8):

$$i > 4O.\ \sqrt{3}.\pi.\varepsilon.n.U/\Delta\alpha \ . \qquad (9)$$

As in most cases $\Delta\alpha = \pi/6$, $\varepsilon = (4.\pi.9.10^9)^{-1}$ F/m, $n = 5/\sqrt{3}$ rot/s, it results that:

$$i\ [\mu A/m]/U[kV] > 10 \ . \qquad (10)$$

The values of i/U might differ a lot from one application to another, and the above inequation can serve only as a preliminary criterium for the evaluation of a corona electrode.

CLASSIFICATION OF CORONA ELECTRODES

There is a wide variety of corona electrodes. It is convenient to classify them in accordance to several criteria, as shown in Table 1.

Table 1
Classifications of corona electrodes of high-tension separators

Criteria of classification	Types of electrodes
Corona-emitting element	a. wire; b. needles; c. blade; d. tips of wire segments
Aspect of negative corona discharge	a. without fixed points of corona discharge (wire, blade); b. with fixed points of corona discharge
Nature of generated field	a. simple (corona); b. dual (corona-electrostatic)
Adjustability	a. adjustable; b. non-adjustable
Function	a. active; b. charge neutralization (wiper electrode)

Dual wire-type electrodes are most commonly used at this time with either industrial and laboratory electroseparators [10], although blade-type electrodes seem to have the most favorable voltage-current diagram [12]. Their corona on-set voltage is lower than that of wire-type electrodes, but the need for sharpening makes them unconvenient for industrial applications. A comparison between the different types of corona electrodes is presented in Table 2.

Table 2

Comparison between different types of corona electrodes

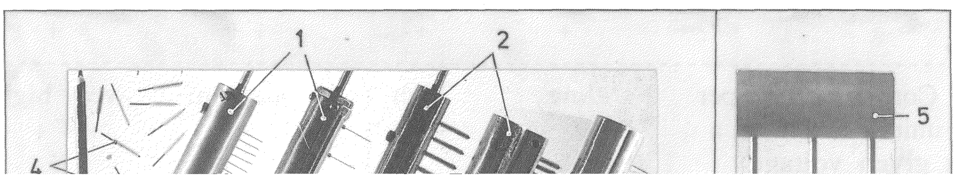
Criteria of comparison	Type of corona element			
	wire	blade	needles	tips of wire segments
Mechanical resistence	poor -	very good + + +	very good + + +	good + +
Ozone generation	low + +	medium +	medium +	high -
Discharge directness	medium +	medium +	high + +	high + +
Corona current per unit of length (at a given voltage)	low -	high + +	medium +	very high + + +
Corona on-set voltage	high -	medium +	medium +	low + +
Maximum power of corona discharge	medium +	high + +	high + +	high + +
Manufacturing difficulties	low + +	low + +	medium +	high -
Cost	low + +	low + +	medium +	high -
Maintainability	poor -	poor -	poor -	good + +

The specific requirements of each application decide which is the most adequate electrode. Instance the case of insulation-metal electroseparators [12], where needle-type electrodes are recommended, because they resist better to mechanical shocks and vibrations, as well as to spark-discharges, which are characteristic to this application.

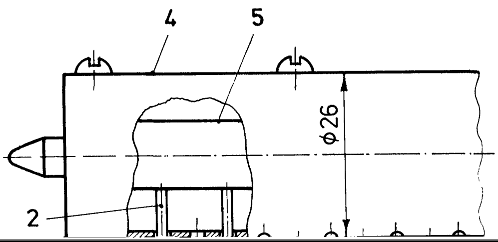
A NEW TYPE OF CORONA ELECTRODE

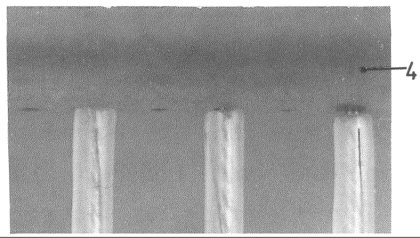
Because of the wear of the needle tips, periodical changing of the corona elements represent an important requirement of the manufacturers in the case that needle-type electrodes are employed with an industrial electroseparator. This might be a considerable inconvenient for the customer, as the operation is time-consumming.

The new electrode design shown in Fig. 2 uses radially-orientated short segments of metallic wire Ø (0.1 ... 0.4) mm, in order to generate the corona discharge. The material of the wire segments is characterized by an elevated melting temperature.



segments 7. Each such wire segment is guided by a radially-orientated metallic tube 6, which can be easily detached of the support 5. The latter variant (Fig. 3) uses the tubular elastic elements 3 to attach the wire segment 1 to the radially-orientated cylindrical metallic supports 2, which are equidistantly-positioned and aligned along the electrostatic support 4.





needed only after several hundreds of operatting hours, and can be manually-done.

DESIGN CONSIDERATIONS

Several experiments have been performed, in order to optimize the design of the electrode. A SPELLMAN high-voltage supply, 50 kV, 6 mA, d. c. has been employed to energize the electrode, which has been mounted at various heights h above a grounded metallic plate. The current has been measured with a galvanometer, and the voltage has been observed using an electrostatic voltmeter.

The distance p between two corona tips represents an important design parameter. This is why a first set of experiments aimed to reveal the influence of "p" on I(U) characteristics of the electrode. As expected, the magnitude of I at a given voltage is greater when p is smaller (Fig.4). But the difference:

$$\Delta I = I(p = 10 \text{ mm}) - I(p = 20 \text{ mm}) \tag{11}$$

is not significant (Fig. 5), so that one can conclude that there is no reason to increase the number of corona tips, and hence the cost of the electrode and of its maintenance beyond a certain limit (correlated with the height h, as shown below).

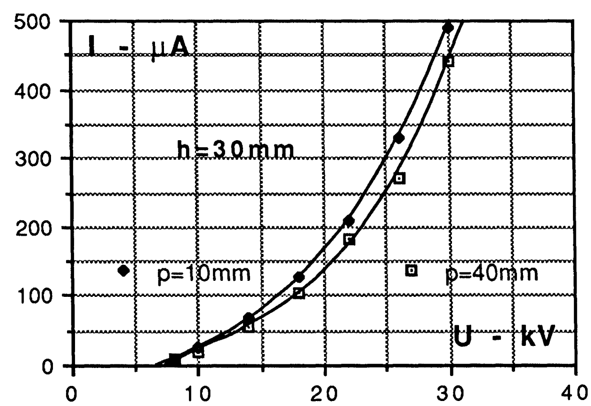


Fig. 4. Influence of p (distance between two adjacent corona-emitting elements) on I(U) characteristics of the active electrode.

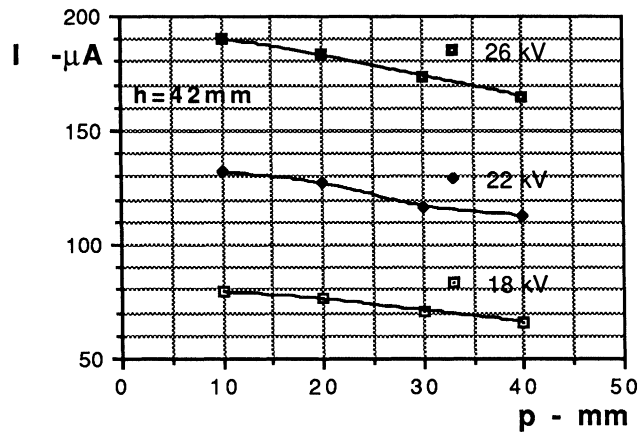
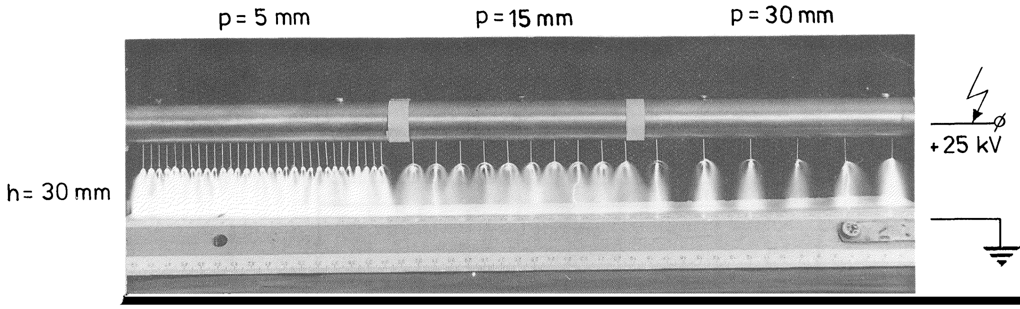


Fig. 5. Corona current (I) vs. the distance between two adjacent corona-emitting elements (p), at different high-voltage levels.

Excessively-reducing the number of corona-emitting wires may affect the uniformity of the space-charge distribution on the surface of the electrode, as shown in Fig. 6. With smaller distances between corona elements, the discharge is more stable (no spark-discharges, at usual operating voltages).

The diameter of the metallic wire segments should be (0.1 ... 0.4) mm. As revealed by a second group of experiments, the corona on-set voltage is lower with smaller diameters, but the overall I(U) characteristic of the electrode is almost unaffected by changing this parameter between the above limits. It was not possible to determine either any systematic modifications of I(U) characteristics when using inoxidable steel wire, instead of wolfram. Anyhow, the material of the wire might influence the long-term behaviour of the electrode. An experiment on this topic is in work on an industrial high-tension separator, operated by ELECTROMURES Co., Tirgu Mures, Romania, with the assistence of the High-Intensity Electric Fields Research Laboratory of the Technical University of Cluj-Napoca.


p = 5 mm
p = 15 mm
p = 30 mm
h = 30 mm
+25 kV

wire-segments. The slope change of $\sqrt{I}(U)$ characteristic (Fig.8) indicates the appareance of back-corona ionisation from the grounded electrode, due to the local intensification of the electric field. Breakdown occures at 14.5 kV (without the granular layer, no spark-discharges could be noticed at voltages twice as high)

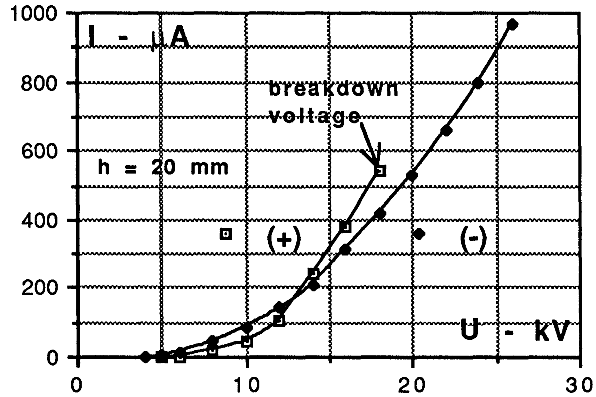


Fig. 7. I(U) characteristic in the absence (curve "-") and in the presence (curve "+" of a mono-layer of electroinsulating granules on the surface of the opposing electrode.

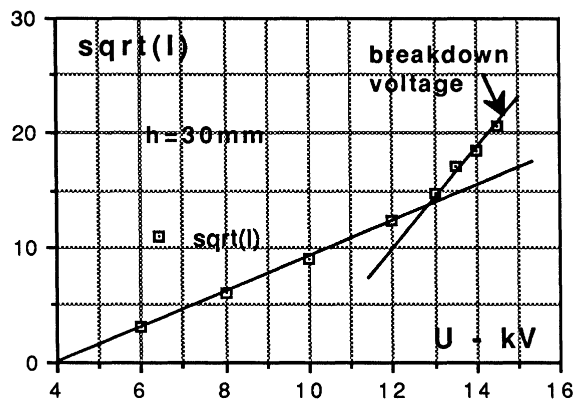


Fig. 8. $\sqrt{I}(V)$ characteristic in the presence of a layer of electroinsulating material on the surface of the opposing electrode (evidence of back-corona emission).

The above experiments revealed that with the new electrode design the inequation (10) is satisfied even at voltages just beyond the corona on-set limit. But (10) represents a necessary condition for the corona-charging efficiency, not a sufficient one. As the maximum charge acquired by a granule is proportional to the electric field E_o, and the electric image forces exerted on the particles increase with E_o^2, the rated voltage U_n of the supply should be chosen considerably higher than the values of U for which the condition (10) is completed. This implies that the rated current of the supply I_n must be higher than the minimum value imposed by corona-charging considerations. The decision on (U_n, I_n) can not be adopted before knowing the limits between which the variation of h could be expected.

The position of the corona electrode with respect to the grounded electrode has a considerable influence on I(U) characteristics (Fig. 9). The small values of the height h should be avoided, because at voltages which ensure the required electric field $E_o > 5$ kV/cm, the current consumption exceeds by far the value imposed by the corona charging condition (10), and the air-gap breakdown is more likely to occur, when the grounded electrode is covered by a layer of electroinsulating granules (as is often the case with high-tension separators). But, as h increases, larger rated voltages are necessary to ensure the minimum corona current.

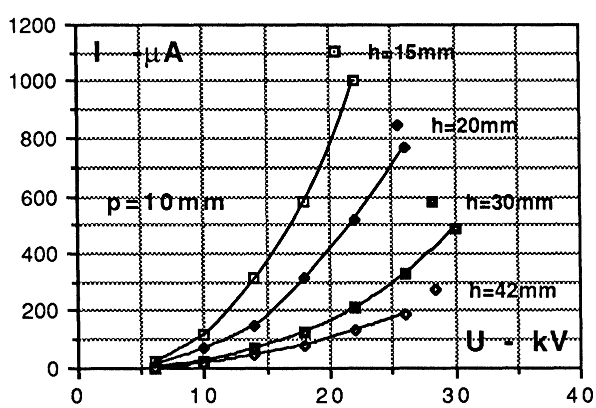


Fig. 9. Influence of electrode position on I(U) characteristic.

In case that various mixtures of granular materials are to be processed on an electroseparator, the facilities for electrode positioning are very important. The electrode carriers should execute both rotational and translational movements, so that up to three electrodes could be positioned in a relatively large region.

CONCLUSIONS

The choice of the corona electrode for a ceratin application has to take into consideration both electrical- and mechanical-performance criteria. It seems that needle-type electrodes achieve the best balance between the various - sometimes contradictory - requirements of employement with industrial high-tension separators.

The new type of corona electrode presented in this paper could represent an alternative to the "classical" solutions. Lower corona on-set voltages, better stability of corona-discharge during long-time operation, shorter maintenance time are the main advantages of the new electrode (Fig. 10).

Fig. 10. Industrial insulation-metal electroseparator (ELSIM-2, manufacturer: ELECTROMURES Co. Tirgu Mures, Romania), provided with the new type of corona electrode; 1 - vibratory feeder; 2 - grounded rotating roll electrode; 3 - corona electrode with radially-orientated emitting wire segments; 4 - electrostatic electrode.

Systematic experiments made on a laboratory model of this electrode enable several design considerations that could be extended to other similar devices. Two industrial high-tension separators at ELECTROMURES Co., Tirgu Mures, Romania, are provided with this type of electrodes (Fig. 10). The operation reports are extremely satisfactory: excellent fiability, and very good efficiency of insulation-metal electroseparation processes.

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