Application of a nanosecond corona discharge generator for electrical separation of ores

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Abstract. The use of a pulsed nanosecond voltage source in a corona separator was investigated. Measurements of the distribution of corona discharge current were obtained. The influence of the interelectrode distance on the distribution of the corona discharge current was investigated. Experiments with gold-bearing quartz-sulfide ore and ilmenite ore were carried out. A concentrate was obtained with a gold content of 48 g/t, a mass equal to 18.7% of the original, which corresponds to the extraction of 92% of gold. The titanium content of ilmenite was enriched from 2.87% to 18.1%.

1. Introduction
One of the areas of electrophysical technologies application is the beneficiation of rocks. In particular, dry separation of minerals based on the difference in electrical properties of different substances using electric corona separators. This method of mineral enrichment is more expedient and environmentally friendly in comparison with flotation methods, since the energy-consuming and expensive operation of concentrate drying is excluded from the enrichment process, there is no water pollution with a flotation reagent, separation can be performed at negative temperatures.

Unfortunately, currently existing models of electro-crown separators (ECS) are characterized by a relatively low specific productivity – at the level of 1–2 t·h per 1 m of the electrode system, which is several times less in comparison with magnetic separation. Since the separation is carried out only in a thin surface layer of the material, an increase in the productivity of the installation is possible only by increasing the speed of material movement through the separation zone, and not by increasing the layer thickness. Accordingly, an urgent task is to increase the rate of transfer of the specific charge to the surface of the material to be separated.

Currently, high-voltage sources of constant voltage are used in electro-corona separators, which imposes a limitation on the high voltage amplitude and, accordingly, on the value of the specific charge transferred from the corona discharge region to the material to be separated. The research undertaken [1] aimed at increasing the overall productivity of the installation does not solve the issue of increasing the specific productivity and consists in increasing the number of electrodes operating in parallel with one settling drum.

We assumed that the use of a frequency generator of high-voltage nanosecond pulses would increase the specific productivity of electro-corona separation. Generators of this type are widely used in rock dressing technologies [2-5]. In our opinion, an increase in the voltage amplitude and specific
2. Schematic diagram of an electro-crown separator

Figure 1 shows a schematic diagram of an electro-crown separator. The corona drum separator consists of a grounded rotating drum, at some distance from which a corona electrode is fixed. A high negative voltage is applied to the corona electrode and the grounded drum is charged positively. In the direction from the corona electrode to the drum, a continuous flow of electrons and negatively charged ions is created, formed due to the ionization of the air. The original ore is fed into the corona discharge zone, where the particles of the mineral rock under the influence of the flow of negatively charged particles are charged negatively and are attracted to the oppositely charged drum. When in contact with the drum, the conductor particles are positively recharged, repelled from the drum and unloaded. Non-conductive negatively charged particles are not recharged from the drum, remain attracted to its surface and are removed with special brushes. The productivity and quality of the separation of mineral rocks is determined by the rate of transfer of the specific charge to the surface of the mineral particles.

3. Experimental setup

Commercially produced ECSs have a collecting electrode (drum) diameter from 120 mm to 400 mm, the linear velocity of particles on the drum surface varies from 1 m/s to 3 m/s, the voltage of high-voltage power supplies is 25-35 kV, the electric field strength in the gap reaches 5 kV/cm. Small diameter drums with high linear speed are used to separate the conductors. For non-conductive rocks, on the contrary, increase the diameter and decrease the speed. To carry out the work, we created a laboratory ECS with a drum diameter of 320 mm and an adjustable rotation speed of up to 300 rpm, which corresponds to a linear speed of up to 5 m/s. The corona discharge was generated using a self-created nanosecond frequency pulse generator (generator was build using semiconductor opening switches [6]) with a voltage of up to 150 kV (electrical circuit is shown in figure 2, the oscillogram is shown on figure 3) or an industrial high-voltage constant voltage source with voltage regulation from 1 to 35 kV. The same corona electrode is used for both sources: a steel wire with a diameter of 0.5 mm.

Initially, experiments were carried out to determine the optimal parameters of the installation, at which the maximum rate of charge transfer from the corona discharge region to the drum with a constant voltage source was achieved. Since the corona discharge current depends directly on the field strength, the strength was set at 5 kV/cm, which corresponds to the maximum values of the known ECS.

The measurement of the amplitude and distribution of the current (charge) over the drum surface is carried out by screening the drum with dielectric plates and gradually opening the gap between the
plates, so that the center of the gap is located along the normal to the corona electrode. In this case, the current is measured through the measuring resistance placed in the open circuit of the drum grounding circuit, the measurement scheme is shown in figure 4. When performing the work, the interelectrode distance was changed and the voltage of the power supply was adjusted to maintain the field strength in the interelectrode gap equal to 5 kV/cm. The results are shown in figure 5.

Figure 2. Electrical circuit.

Figure 3. Pulse oscillogram, amplitude 150 kV, pulse width 50 ns.

Figure 4. Measurement scheme.

Figure 5. Distribution of charge.

Figure 6. Corona discharge current.
As can be seen from figure 4, the maximum charge and the maximum area of the drum surface, on which the charge from the corona discharge zone is deposited, is achieved at an interelectrode distance of 65 mm. An increase in the field strength to 5.2–5.5 kV/cm leads to local breakdowns in the air gap of the interelectrode gap. Further, at a given distance, the corona discharge current was measured at various values of the voltage (field strength), figure 6.

As follows from figure 6, the charge transferred in 1 second is 82 μC. Next, we measured the charge that is transferred to the drum when using a high-voltage nanosecond pulse generator. The duration of the voltage pulse at the level of 30 ns makes it possible to increase the tension in the interelectrode gap up to 20–25 kV/cm without breakdown of the air gap. Therefore, a pulse generator with a voltage of 150 kV was created, which, while maintaining the interelectrode gap equal to 65 mm, leads to the formation of a field with an intensity of up to 23 kV/cm. After exposure to 1 pulse, the charge accumulated on the capacitor C (capacity - 2.2 nF) was measured.

The capacitor was charged at 2.73 kV in 1 pulse, which corresponds to a charge of 6 μC. Figure 7 shows the dependence of the transferred charge on the distance between the corona electrode and the drum.

![Figure 7. Transferred charge measurement.](image)

For one pulse, with an interelectrode distance of 65 mm, about 6 μC is transmitted. In the experiment, stable operation of the generator was achieved at a pulse repetition rate of 200 Hz. This corresponds to a charge of 1200 μC and is 14 times higher than the ECS with a constant voltage source. As previously shown in figure 3, the width of the stripe of the collecting electrode, on which the main charge is deposited from the corona discharge region, with an interelectrode gap of 65 mm, is 5–6 cm.

During the time between pulses, at a pulse repetition rate of 200 Hz and a drum linear speed of 5 m/s, the drum surface will move by 2.5 cm. Therefore, it is possible to implement the separation mode using frequency nanosecond corona discharge generators with 100% processing of the separated material. The operating frequency of the pulse nanosecond generator can be increased to 1000 Hz due to the introduction of an active cooling system for the thyristor inverter and the current breaker, while the amount of charge falling on the drum will be 6000 μC.

4. Experiments with rock samples
To confirm the increase in the performance of the ECS when replacing the corona discharge generator from a constant voltage source to a frequency nanosecond generator, experiments were carried out to separate gold-bearing sulfide-quartz ore, figure 8. Since finely disseminated gold is associated with pyrite, the separation task is to separate the original ore into a pyrite-containing concentrate and a quartz tail. Previously, the starting material was dedusted, and for experiments, ore with fractions of -0.300 + 0.100 mm with a gold grade of 9.9 g/t was taken. For quantitative measurements of the content of the products of interest in the concentrate, both assay melting and X-ray fluorescence
analysis were used. A concentrate was obtained with a gold content of 48 g/t, a mass equal to 18.7% of the original, which corresponds to the extraction of 92% of gold. At the same time, the specific productivity of the EKS installation with a nanosecond corona discharge generator reached 3.7 t·h per 1 m of the electrode system.

Also, work was carried out to enrich ilmenite with an initial mass content of Ti of 2.87%. As a result of separation, it is possible to isolate a concentrate with a Ti content of 18.1%.

![Figure 8](image-url) **Figure 8.** Separation of gold-bearing ore.

5. **Conclusion**

Comparative studies of a high-voltage pulse generator and a constant voltage source show that the use of a nanosecond generator makes it possible to increase the interelectrode gap by 4 times from 5 to 23 kV/cm without deteriorating the reliability and dielectric strength of the nodes. This, in turn, leads to an increase in the corona charge from 80 μC for a constant voltage source to 6000 μC for a pulse generator at a pulse repetition rate of 1000 Hz.

The studies carried out allow us to assert that the use of a pulsed nanosecond high-voltage source for generating a corona discharge will sharply increase the specific productivity of electric separators without deterioration of the quality of the resulting concentrates.

**References**

[1] Vereshchagin I P 1999 High-voltage electrical technologies (Moscow: MPEI) pp 81–5
[2] Kotov Yu A, Mesyats G A, Filatov A L, Korzhenevskii S R, Motovilov V A, Shcherbinin S V, Boriskov F F and Koryukin B M 2000 *Dokl. Earth Sci.* 373 790–2
[3] Korzhenevsky S R, Bessonova V A, Komarsky A A, Motovilov V A and Chepusov A S 2016 *J. Min. Sci.* 52 493–6
[4] Filatov A L, Kotov Y A, Korzhenevski S R, Motovilov V A, Jakovlev V L, Korykin B M and Boriskov F F 1997 *Digest of Technical Papers. 11th IEEE International Pulsed Power Conference* (Cat. No.97CH36127) vol 2 (Baltimore: IEEE) pp 1103–5
[5] Kotov Yu A, Mesyats G A, Korzhenevski S R, Motovilov V A, Rukin S N, Scotnikov V A and Filatov A L 1995 *Digest of Technical Papers. Tenth IEEE International Pulsed Power Conference* (Albuquerque: IEEE) pp 1235–8
[6] Rukin S N 2020 *Rev. Sci. Instrum.* 91 011501