TRANSLATION

CHARGING SOLID PARTICLES AND DROPS
IN AN ELECTRIC FIELD

BY

Ye. V. Moiseyev

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

WRIGHT-PATTERSON AIR FORCE BASE

OHIO

UNEDITED ROUGH DRAFT TRANSLATION

CHARGING SOLID PARTICLES AND DROPS IN AN ELECTRIC FIELD

BY: Ye. V. Moiseyev

English Pages: 7

SOURCE: Russian periodical, Referativnyy zhurnal. Khimiya. No. 15, 1961, Pp. 55-57.

S/81-61-0-15-125/139

CHARGING SOLID PARTICLES AND DROPS IN AN ELECTRIC FIELD

Ye. V. Moiseyev

The application of non-metallic coatings to the surfaces of articles is a very laborious operation which is usually carried out by hand. Therefore at present there has begun to come into wide use a method of electric field painting which can be mechanized and automated. Automation is achieved by depositing the charged material in an electric field on the articles, which are hung on a conveyer.

By the method of electric field painting are deposited lacquers and paints, powdered materials for different purposes, and flocking on fabrics, paper, and metal to imitate plush, velvet, and velour.

From the physical point of view the process of applying coatings in an electrical field consists in electrically charging the particles, moving them, and depositing them on the article.

The amount of charge on the particles of the material exerts a great influence on the movement of the particles to the article and their deposition thereon. As the charge on the particles increases, so do the forces of the electric field. In addition, the larger the charge that a drop of paint has received, the better it is atomized

into small droplets by the forces of the electric field.

In order to use the forces of the electric field practically, the influence which the properties of the material to be deposited and the size of the electrode exert on the charge on the particle must be clarified.

The particles may be charged by ion deposition in the electric field of a corona electrode and contact charge on the sharp edge of an electrode, and also by a combination of the two methods.

Ye. M. Balabanov [1] investigated the charging of drops and solid particles with a corona electrode. For particles of $\rho > 1\mu$ the following formula may be practically used

$$Q_{max} = \left(1 + 2\frac{\epsilon - 1}{\epsilon + 2}\right) E\rho^2 \qquad (1)$$

where Q_{max} is the greatest possible charge acquired by the particle; ϵ, the dielectric constant of the particle; E, the intensity of the field at a given point; and ρ, the particle radius.

Formula (1) is used under ordinary conditions in practice, i.e., when securing an ion concentration sufficient to charge all the particles in the chamber.

Below is examined the case of contact charging the paint on the sharp edge of the atomizer (bowl, mushroom, or pan-shaped), which does not differ from contact charging solid particles.

Two metallic electrodes (Fig. 1), the article and the atomizer with r as the radius of the sharp edge, are connected with a source of high voltage. Between the electrodes at distance H there is a layer of air (dielectric constant $\epsilon_2 = 1$) and a thin layer of paint (electrical conductivity γ_1, dielectric constant ϵ_1, layer thickness d) on the bowl, i.e., two layers of dielectrics which may be considered as a two-layered insulation. As is known, in two-layered insulation

with electrical conductivity on the dividing surface of the layers there appears a free charge [2]. When a high voltage is turned on, the field strength in the paint layer and around the surface of the paint at first propagates as follows (field strength in thin paint layer taken as constant):

$$\frac{E_1^0}{E_2^0} = \frac{\epsilon_2}{\epsilon_1} \qquad (2)$$

where E_1^0 and E_2^0 are the intensity of the field and ϵ_1 and ϵ_2, the dielectric constant of the layers.

Since the paint and air layer is electrically conductive, conduction currents will appear in them under the influence of the primary voltage. Near the sharp edge of the atomizer covered with paint the field strength is great, causing a current to originate from the superficial paint layer because of corona discharge. The paint layer and the corona layer of the air have different conductances; therefore on the surface of the paint a charge accumulates (in our case a negative one). The process finishes when the currents of conductance in both layers are equal and the accumulation of the charge on the paint ceases.

In the stationary state in accordance with the equilibrium and continuity of the current

$$i_1 = i_2 \qquad (3)$$

where i_1 is the current passing through the paint and i_2, that passing through the air.

The current passing through the paint follows Ohm's law up to a field strength of 15-20 kv/cm; when the field strength is greater the current increases more rapidly than in accordance with Ohm's law [2, 3], and is expressed by the formula

$$i_0 = i_{0c}^{C(U_0 - U_c)} = i_{0c}^{C\gamma E_0 d} \qquad (4)$$

where E_o, i_o, U_o are the field strength in the paint layer, the current, and the voltage at which the current begins to grow faster than according to Ohm's law, respectively; d, the thickness of the paint layer; and C, the coefficient depending on the thickness of the layer; $i_o = \gamma \frac{U_o}{d}$, γ being the electrical conductance of the paint.

In practice the field strength in the paint layer generally exceeds 20 kv/cm. Let us examine this case.

The current passing through the air gap will be equal to the current leaving the corona electrode if the surface acting as a conductor is also expressed by the formula

$$i_1 = \frac{0.78K}{H \cdot \ln \frac{2H}{r}} U_1 (U_1 - U_c) \qquad (5)$$

where K is 1.9 $cm^2/sec \cdot v$ (ion mobility); H, distance from edge of atomizer to article; r, radius of sharp edge of atomizer; and U_c, voltage triggering the corona.

$$U_c = 31\left(1 + \frac{0.3}{\sqrt{r_{cl}}}\right) r \ln \frac{2H}{r} \qquad (6)$$

After conversions and reduction of the area to 1 cm^2 we obtain

$$e^{C(U - U_0 - U_c)} = \frac{0.39 \cdot K \cdot A \cdot d}{\gamma U_c H \cdot \ln \frac{2H}{r}} (U_1 - U_c) U_1 \qquad (7)$$

where $A = 1/(9 \cdot 10^{11})$ (constant); U, voltage of power source; γ, electrical conductance of the paint; and U_c, the corona triggering voltage.

From Eq. (7) we can determine U_2 and then U_1

$$U_1 = U - U_2 \qquad (8)$$

From the values of U_1 and U_2 we can determine the field strength within the layers, considering that the E_1 is roughly a constant in the thin paint layer:

$$E_1 = \frac{U_1}{d} \tag{9}$$

$$E_{2_{max}} = K \frac{U_2}{r \ln \frac{2H}{r}} \tag{10}$$

where K = 0.9 is the coefficient for the given case determined by graphic calculation of the field of the bowl; E_1, field strength in the paint layer; and $E_{2_{max}}$, field strength in the air around the paint layer.

The surface density of the charge on the electrode (metal of the bowl) is

$$\sigma_1 = \frac{\varepsilon_1 \varepsilon_0}{4\pi} \tag{11}$$

The field strength $E_{2_{max}}$ also determines the total of the charges on electrode σ_1 and on the surface of the paint layer σ_2:

$$\varepsilon_{0max} = 4\pi(\sigma_1 + \sigma_2) \tag{12}$$

Whence

$$\sigma_2 = \frac{\varepsilon_{0max}}{4\pi} - \sigma_1 \tag{13}$$

The density of the charge on the paint is

$$\sigma_0 = \frac{\varepsilon_{1max} - \varepsilon_1 \varepsilon_0}{4\pi} \tag{14}$$

To determine the dependence of the size of the charge of the paint on the different conditions we take this charge as the unit in the following initial parameters: U, 100 kw; γ, 10^{-9} ohm·cm; ϵ, 4; K, 1.9 $cm^2/sec \cdot v$; H, 20 cm; r, 0.125 mm; d, 10μ; and C, 0.1.

Calculating from the formulas quoted above results in our obtaining the following parameter values: U_1, 42 v; E_1, 42 kw/cm; $E_{2_{max}}$, 890 kw/cm; and σ_2, 192 unit cgs e/cm^2.

The size of the charge of a particle with radius ρ = 5μ will be

$$Q = \frac{1}{3} S \cdot \sigma_2 = \frac{1}{3} \cdot 192 \cdot 3{,}14 \cdot 10^{-6} \approx \approx 2 \cdot 10^{-4} \text{ ед. cgs } e \tag{15}$$

where S is the whole surface of the particle and 1/3 is the portion of the particle surface on which the charge accumulates.

With a change in size of any of the initial parameters the value of the surface density of the charge changes (Figs. 2-5). The figures show that when the voltage of the power source is raised, as well as the electrical conductance of the paint, the paint charge increases. When the radius of rounding of the atomizer is increased, the paint charge decreases. Similar results are obtained when the flow rate of the paint is increased; when the dielectric constant of the paint increases, the charge decreases.

We should bear in mind that the dielectric constant of the material exerts an influence on the whole process of atomizing the drops, therefore it is not recommended that its size be diminished.

For comparison let us determine the size of the charge of the same particle which it got in the field of the corona electrodes when E = 16.6 unit cgs e/cm

$$Q_{max} = \left(1 + 2\frac{\varepsilon - 1}{\varepsilon + 2}\right) 16{,}6 \cdot 5^2 \cdot 10^{-6} = 8{,}4\ 10^{-6}\ \text{ед. cgs } e \qquad (16)$$

Contact charging gives in the present case a charge value 25 times larger than does charging in the field of the corona electrode.

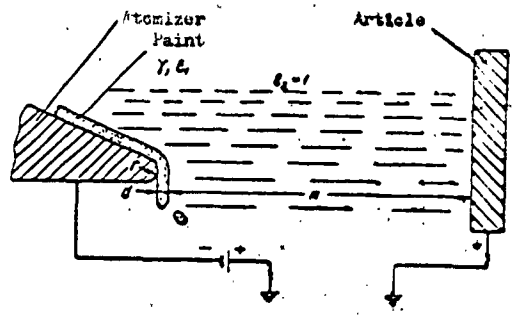

Fig. 1. Diagram of contact charging of paint particles on sharp edge of atomizer.

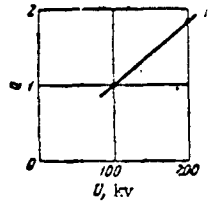

Fig. 2. Dependence of value of particle charge on voltage of power supply.

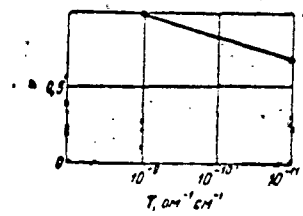

Fig. 3. Dependence of value of particle charge on electric conductance of paint.

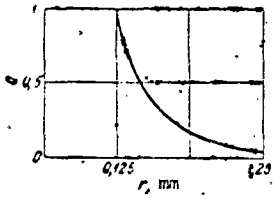

Fig. 4. Dependence of value of particle charge on radius of rounding of paint atomizer.

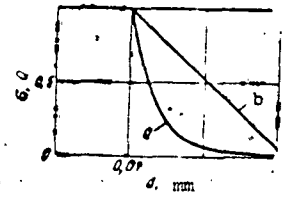

Fig. 5. Dependence of value of charge and its density on thickness of paint layer.

Conclusions

The electrical charge of solid particles or drops of paint in contact charging is achieved as a result of raising the voltage of the power source, of using material with high electrical conductance, of sharp rounding of the atomizer, and of decreasing the thickness of the layer of material on the edge of the electrode.

Since certain variables simultaneously influence the size of the charge it is necessary strictly to maintain the technological regime according to the voltage, paint flow rate, and electrical parameters of the material.

REFERENCES

1. Ye. M. Balabanov. Author's abstract of dissertation "Dispersed Systems in the Electrical Field of a Corona Discharge," 1954.

2. G. I. Skanavi. The Physics of Dielectrics, 1949.

3. A. Nikuradze. Fluid Dielectrics, 1936.

4. N. A. Kaptsov. Electrical Phenomena in Gases and Vacuum, 1947.

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE	Nr. Copies
HEADQUARTERS USAF	
AFCIN-3D2	1
ARL (ARB)	1
OTHER AGENCIES	
CIA	1
NSA	6
DIA	9
AID	2
OTS	2
AEC	2
PWS	1
NASA	1
ARMY (FSTC)	3
NAVY	3
NAFEC	1
PGE	12
RAND	1

MAJOR AIR COMMANDS	Nr. Copies
AFSC	
SCFDD	1
DDC	25
TDBTL	5
TDBDP	5
AEDC (AEY)	1
SSD (SSF)	2
ESD (ESY)	1
RADC (RAY)	1
AFSWC (SWF)	1
AFMTC (MTW)	1
ASD (ASYIM)	1