UFS Corporation
330 North 400 East
Valparaiso, IN 46383-9704 USA
PH: 219-464-2027 FAX: 219-464-8646
www.ufsc.com
email: service@ufsc.com

Technical Reference

Topic: Conductivity, Resistance, & Resitivity

Many paint manufacturers use ***conductivity*** as a key yardstick of e-coat performance. Other paint suppliers prefer to talk in terms of ***resistivity. Resistance***, which is related to but not the same as resistivity, is another important electrical term that has meaning for most people.

The remainder of this bulletin clarifies the relationship between these terms. It is a useful exercise because it provides insight into some important concepts behind electrocoating and the performance of anode cells.

DEFINITIONS

Resistivity (r) – is the specific resistance of a substance in ohm-cm. More explicitly, the resistivity of a substance is the specific resistance between two parallel faces of a one centimeter cube of the substance. It is a property of the material.

Resistance (R) – is defined by Ohm's law as the constant of proportionality between a voltage gradient (E) and current flow (I):

$$R\ (ohms) = E(volts)/I\ (amps)$$

Resistance is also related to resistivity by the following equation that includes the length (L) and the cross-sectional area (A) of the matter:

$$R\ (ohms) = R(ohm\text{-}cm) \times L\ (cm)/A(cm^2)$$

In other words, one cannot talk about resistance without making some assumptions about the dimensions of the resistive element. This is obvious if one thinks about a piece of wire in an electrical circuit: its resistance is a function of its length and diameter. The same is true in electrocoating. The electrical resistance between the anode in a cell and a point on the cathode is dependent on the length of the current path between them and on the current "density", expressed in amps per unit of cross-sectional area.

Conductivity (k) – is merely the reciprocal of resistivity. The reciprocal of an ohm is defined as a mho, so the units of conductivity are usually mhos/cm. Electrocoat paint resistivity is fairly high; therefore conductivity is quite low. Thus, paint conductivity is often expressed as micromhos/cm (10^{-6}mhos/cm) or microsiemens/cm (a siemen is approximately equal to one mho).

SAMPLE CALCULATION

Paint conductivities vary depending on the paint type and manufacturer, but as an example, consider a paint with a conductivity of 1400 micromhos/cm. The resistivity of this paint is:

$$R(resistivty) = 1/k(conductivity) = 1/1400 \times 10^{-6}\ mhos/cm = 714\ ohm\text{-}cm$$

Thus, one can use this calculation to compare paint from different manufacturers that specify their paints in different ways.

To translate this number into resistance, one must specify a path length and a cross-sectional area through which the current would flow. Continuing the previous example, the resistance between two parallel faces of a one foot cube of paint would be:

$$R\ (ohms) = r\ (resistivity) \times L\ (length)\ /\ A\ (area) = (714\ ohm\text{-}cm \times 1\ ft/1ft^2) \times (1\ ft/30.48\ cm)$$

= 23.4 ohms

By Ohm's Law, the voltage required to cause 1 amp/ft^2 of current density to flow through one foot of this paint would be 23.4 volts.

Practical Implications

This illustrates that electrocoat paint is the cause of a significant portion of the electrical resistance between the anode and cathode. For example, as a typical anode current density of 3 amps/ft^2 and typical applied voltage of 250V, approximately 70V, or almost 30% of the total voltage, is consumed just getting through the first one foot of paint! Of course, as the current approaches the cathode, it spreads out over the larger cathode area and thereby reduces the current density and voltage consumed per unit of path length. However, the paint path resistance is still the cause of much of the voltage required for electrocoating.

The cost-conscious electrocoater should constantly try to minimize the voltage required to achieve the desired coating. Any voltage above the minimum costs money in two ways. First, power consumption in kw-hr is directly proportional to voltage. Second, any excess voltage required due to paint resistance is converted to heat, which must be removed by the heat exchanger.

TECTRON Membrane Electrode Cells can be optimally spaced to minimize paint path resistance. In this illustration, a paint tank has 5 box cells equidistantly spaced on one side and 20 TECTRON Membrane Electrode Cells equidistantly spaced on the other, with both sides having the same anode area. Even though the box cells cover 50% of the tank wall area, their throwpower is ineffective when the work package is not directly in front of a box cell. TECTRON Membrane Electrode Cells, on the other hand, are spaced on one-foot centers, and the work package is virtually always in front of a TECTRON Membrane Electrode Cell. With a shorter average distance between anodes and the work, there is minimized paint path resistance.

For more information, call UFSc at the phone number show above.

Think and act in a safe manner. Always disconnect power and use a lockout before you work on the E-coat system. Observe any confined space conditions. Use the appropriate safety equipment & clothing for the task.