Answer. (a).

28.5 Calorizing is the same as which one of the following surface processes: (a) aluminizing, (b) doping, (c) hot sand blasting, or (d) siliconizing?

Answer. (a).

28.9 Which one of the following plate metals produces the hardest surface on a metallic substrate: (a) cadmium, (b) chromium, (c) copper, (d) nickel, or (e) tin?

Answer. (b).

28.10 Which one of the following plating metals is associated with the term galvanizing: (a) iron, (b) lead, (c) steel, (d) tin, or (e) zinc?

Answer. (e).

28.11 Which of the following processes involves electrochemical reactions (two correct answers): (a) anodizing, (b) chromate coatings, (c) electroless plating, (d) electroplating, and (e) phosphate coatings?

Answer. (a) and (d).

28.12 With which one of the following metals is anodizing most commonly associated (one answer): (a) aluminum, (b) magnesium, (c) steel, (d) titanium, or (e) zinc?

Answer. (a).

28.13 Sputtering is a form of which one of the following: (a) chemical vapor deposition, (b) defect in arc welding, (c) diffusion, (d) ion implantation, or (e) physical vapor deposition?

Answer. (e).

28.14 Which one of the following gases is the most commonly used in sputtering and ion plating: (a) argon, (b) chlorine, (c) neon, (d) nitrogen, or (e) oxygen?

Answer. (a).

28.15 The principal methods of applying powder coatings are which of the following (two best answers): (a) brushing, (b) electrostatic spraying, (c) fluidized bed, (d) immersion, and (e) roller coating?

Answer. (b) and (c).

28.16 Porcelain enamel is applied to a surface in which one of the following forms: (a) liquid emulsion, (b) liquid solution, (c) molten liquid, or (d) powders?

Answer. (d).

28.17 Hard facing utilizes which one of the following basic processes: (a) arc welding, (b) brazing, (c) dip coating, (d) electroplating, or (e) mechanical deformation to work harden the surface?

Answer. (a).

Problems

Electroplating

28.1 What volume (cm^3) and weight (g) of zinc will be deposited onto a cathodic workpart if 10 amps of current are applied for one hour?

Solution: From Table 29.1, $C = 4.75 \times 10^{-2}$ mm^3/A-s, cathode efficiency $E = 95\%$.
Volume $V = ECIt = 0.95(4.75 \times 10^{-2}\ mm^3/A\text{-}s)(10\ A)(1\ hr)(3600\ s/hr)$ = **1624.5 mm^3**
= **1.6245 cm^3**

Density of zinc from Table 4.1 $\rho = 7.15$ g/cm^3. Weight $W = 1.6245(7.15) =$ **11.615 g**

28.2 A sheet metal steel part with surface area = 100 cm^2 is to be zinc plated. What average plating thickness will result if 15 amps are applied for 12 minutes in a chloride electrolyte solution?

Solution: From Table 29.1, $C = 4.75 \times 10^{-2}$ mm^3/A-s, cathode efficiency $E = 95\%$.
Volume $V = ECIt = 0.95(4.75 \times 10^{-2}$ mm^3/A-s)(15 A)(12 min)(60 s/min) = 487.35 mm^3
Area $A = 100$ cm^2 = 10,000 mm^2
Plating thickness $d = 487.35$ mm^3/10,000 mm^2 = **0.049 mm**

28.3 A sheet metal steel part with surface area = 15.0 in^2 is to be chrome plated. What average plating thickness will result if 15 amps are applied for 10 minutes in a chromic acid-sulfate bath?

Solution: From Table 29.1, $C = 0.92 \times 10^{-4}$ in^3/A-min, cathode efficiency $E = 15\%$.
Volume $V = ECIt = 0.15(0.92 \times 10^{-4})(15)(10) = 0.00207$ in^3.
Plating thickness $d = 0.00207/15 =$ **0.000138 in.**

28.4 Twenty-five jewelry pieces, each with a surface area = 0.5 in^2 are to be gold plated in a batch plating operation. (a) What average plating thickness will result if 8 amps are applied for 10 min in a cyanide bath? (b) What is the value of the gold that will be plated onto each piece if one ounce of gold is valued at $900? The density of gold = 0.698 lb/in^3.

Solution: (a) From Table 29.1, $C = 3.87 \times 10^{-4}$ in^3/A-min, cathode efficiency $E = 80\%$.
Volume $V = ECIt = 0.80(3.87 \times 10^{-4})(8)(10) = 0.02477$ in^3.
With $Q = 25$ pieces and average area per piece = 0.5 in^2, total area $A = 25(0.5) = 12.5$ in^2
Plating thickness $d = 0.02477/12.5 =$ **0.00198 in**.

(b) Given density for gold $\rho = 0.698$ lb/in^3
Weight of plated gold = (0.698 lb/in^3)(0.02477 in^3) = 0.01729 lb = 0.277 oz.
At $300/oz, the total value of plated gold = $900(0.277) = $249.30
The value per piece is $249.30/25 = **$9.97**

28.5 A part made of sheet steel is to be nickel plated. The part is a rectangular flat plate that is 0.075 cm thick and whose face dimensions are 14 cm by 19 cm. The plating operation is carried out in an acid sulfate electrolyte, using a current = 20 amps for a duration = 30 min. Determine the average thickness of the plated metal resulting from this operation.

Solution: From Table 29.1, $C = 3.42 \times 10^{-2}$ mm^3/A-s, cathode efficiency $E = 95\%$.
Volume $V = ECIt = 0.95(3.42 \times 10^{-2}$ mm^3/A-s)(20 A)(30 min)(60 s/min) = 1169.6 mm^3
Area $A = 2(19 \times 14) + 0.075 \times 2(19 + 14) = 536.95$ cm^2 = 53,695 mm^2
Plating thickness $d = 1169.6/53{,}695 =$ **0.022 mm**

28.6 A steel sheet metal part has total surface area = 36 in^2. How long will it take to deposit a copper plating (assume valence = +1) of thickness = 0.001 in onto the surface if 15 amps of current are applied?

Solution: From Table 29.1, $C = 2.69 \times 10^{-4}$ in^3/A-min, cathode efficiency $E = 98\%$.
Required volume of plate metal = 36(0.001) = 0.036 in^3
Plated volume $V = ECIt = 0.98(2.69 \times 10^{-4}$ in^3/A-min)(15 A) $t = 0.003954\ t$ in^3
$0.003954\ t = 0.036$ $t = 0.036/0.003954 =$ **9.1 min.**

28.7 Increasing current is applied to a workpart surface in an electroplating process according to the relation $I = 12.0 + 0.2t$, where I = current, amps; and t = time, min. The plating metal is chromium, and the part is submersed in the plating solution for a duration of 20 min. What volume of coating will be applied in the process?

Solution: From Table 29.1, $C = 0.92 \times 10^{-4}$ in^3/A-min, cathode efficiency $E = 15\%$.
Plated volume $V = EC\int I dt = EC\int(12 + 0.2t)dt = EC(12t + 0.1t^2)$ over the range 0 to 20 min.

$V = 0.15(0.92 \times 10^{-4})(12 \times 20 + 0.1(20)^2) =$ **0.00386 in^3**

28.8 A batch of 100 parts is to be nickel plated in a barrel plating operation. The parts are identical, each with a surface area $A = 7.8$ in^2. The plating process applies a current $I = 120$ amps, and the batch takes 40 minutes to complete. Determine the average plating thickness on the parts.

Solution: From Table 29.1, $C = 1.25 \times 10^{-4}$ in^3/A-min, cathode efficiency $E = 95\%$.
Volume $V = ECIt = 0.95(1.25 \times 10^{-4})(120)(40) = 0.57$ in^3.
Area $A = 100(7.8) = 780$ in^2 Plating thickness $d = 0.57/780 =$ **0.00073 in.**

28.9 A batch of 40 identical parts is to be chrome plated using racks. Each part has a surface are = 22.7 cm^2. If it is desired to plate an average thickness = 0.010 mm on the surface of each part, how long should the plating operation be allowed to run at a current = 80 amps?

Solution: From Table 29.1, $C = 2.5 \times 10^{-2}$ mm^3/A-s, cathode efficiency $E = 15\%$.
Volume $V = ECIt = 0.15(2.5 \times 10^{-2}$ mm^3/A-s)(80 A)$t = 0.3t$ mm^3
With $Q = 40$ pieces and average area per piece = 22.7 mm^2,
total area $A = 40(22.7) = 908$ cm^2 = 90,800 mm^2
Plating thickness $d = V/A = (0.3\ t$ mm$^3)/(90{,}800$ mm$^2) = 0.03304(10^{-4})\ t$ mm
Given that $d = 0.010$ mm, $0.03304(10^{-4})\ t = 0.010$
Thus, $t = 0.010/0.03304(10^{-4}) = 0.3027 \times 10^4 =$ **3027 s = 50.44 min**.