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*Plating Processes*

*Room Temperature Antiquing &  
Metal Blackening Processes*

*Hot Black Oxide Finishes*

*Metal Cleaning & Surface Preps*

*Phosphate Finishes, Chromates & Rust Preventatives*

## **How to Select an Electroplated Finish?**

There are many variables and opportunities when you select an electroplated finish. You can request a bright and shiny finish like chrome plated wheels or chrome plated Harley Davidson parts, to highly corrosion resistance electroless nickel, and inexpensive corrosion resistant zinc plating processes.

This paper will provide a brief review of the many finishes available going through these variables:

- What is the substrate you want to finish?
- Is this functional, decorative, or functional/decorative?
- Do you have any ASTM, military, or in-house specifications? Corrosion/Salt Spray?
- How long do you want the finish to last?
- What is your budget?
- Environmental/EPA/OSHA/ REACH concerns?

This paper will go over these points briefly discussing the various types of zinc, nickel, copper, tin, precious metals (silver, gold, etc.), phosphate, black oxide, and more.

### **Effect of Environmental Factors**

The atmospheric environment is unquestionably the largest factor when selecting a metal finishing process. For this paper, we will classify the atmospheric environments as follows:

- (1) Generally dry exposure sheltered from rain and dew, that is indoor exposure;
- (2) Direct exposure to the elements that is outdoor exposure, which can be categorized in the following four categories:
  - a. Industrial/Urban
  - b. Marine/Seacoast
  - c. Tropical
  - d. Rural

Most indoor applications are low humidity except where condensation can occur on the metal like bathrooms and kitchens. The outdoor applications are affected by the rain, dew, sun, and atmospheric constraints, which include soluble and insoluble solids, liquids, or gases. The rain and dew, together with the soluble material, provide an electrolyte which promotes galvanic effects normally absent in dry indoor locations.

In general, industrial and marine exposures are much more severe on finishes than rural exposures, while tropical exposures typically fall in the middle. Industrial or urban atmospheres are characterized as sulfur-containing gases and dust derived from the oxidation of fuels, coastal atmospheres by the chloride content, and tropical by the high temperature and humidity.

### **Zinc, Zinc Alloy, or Cadmium Finishes for Steel**

Why apply the finishes?

- Rust Prevention
- Appearance
- Functional Service

#### Rust Prevention

Red rust is the corrosion product of steel. White rust is the corrosion product of zinc and is very voluminous. When zinc corrodes it, the white corrosion product grows to a larger thickness than the zinc plate. Therefore, it is voluminous. The cadmium corrosion product is not voluminous. It is thin and slightly grey in color. Therefore, a cadmium plated lock versus a zinc plated one that was exposed to the outdoor elements for ten years will still open. Why do zinc and cadmium stop the rust - because of the electrochemical potentials as compared to steel.

#### Appearance

Luster, gloss, and brightness sells. The consumer wants bright and shiny parts like jewelry, which are perceived as higher quality. Zinc and cadmium coatings are available in clear, blue, yellow, black, olive drab, and also dyed colors.

#### Functional Service

Some examples of functionality are:

- Solderability and surface conductivity on electronic equipment
- Lubricity prevents moving parts from seizing
- High temperature environments

#### Rust Prevention

In severe marine atmospheres, cadmium and tin-zinc are more effective than zinc. Zinc cobalt shows greater ability to prevent the spread of red rust versus zinc only. All zinc alloys offer better corrosion protection than straight zinc.

#### Corrosion Behavior

Zinc by itself in a humid environment produces a white, bulky corrosion product. Cadmium does not generate this bulky corrosion product. To provide a longer white corrosion resistance a chromate or passivation of it is necessary.

#### Solderability

Cadmium and tin-zinc can be readily soldered.

### Electrical Properties

Cadmium and tin-zinc have a lower contact resistance than zinc.

### Whiskering

Zinc can exhibit whiskering or formation of dendrite crystal growth. All zinc alloys do not form those crystals.

### Hydrogen Embrittlement

High carbon and high strength steel having a hardness greater than 35 Rockwell C are susceptible to embrittlement caused by hydrogen in the processing of the steel in machining, pickling, cathodic cleaning, or plating operations. The actual cause of hydrogen embrittlement is still being debated, but the majority agrees that baking of suspected steel parts after machining and plating reduces the danger of subsequent cracking. Bake as soon as possible at 191°C (375°F) for four hours. To learn more, see ASTM B-242 specification on hydrogen embrittlement.

### Specify the Finish

Thickness is most important. 1.0 mil (0.001”) = 25.4 microns = 1000 microinches. You need to determine if you are going to have a mild, moderate, severe, or very severe degree of exposure. Next, determine the corrosion resistance and color you need.

### ASTM Thickness Charts

Table 1 is ASTM B-633 lists the thickness classes are related to the service condition. There are four types of service conditions: SC 4 (very severe), SC 3 (severe), SC 2 (moderate), and SC 1 (mild) related to thickness class. To see all these, you have to get the spec ASTM B-633.

Table 2 lists the finish type and corrosion resistance requirements (salt spray hours). There are six different types of finishes/corrosion resistances.

### Testing the Finish

Thickness testing methods:

- X-ray
- Magnetic

Protective value:

- Compound Cyclic Corrosion Test
- Salt Spray – ASTM B-117
- Lead Acetate Spot Test

## **Chromate and Passivates**

Bare zinc electroplate shows white corrosion in less than 1 hour. Hexavalent Chromates: Clear Blue – 24 -48 hrs, Yellow 72-120 hrs, Olive Drab – 150-250 hrs, Black – 48-200 hrs. When you scratch (parts tumbling on each other) with a hexavalent chromate, you will still get corrosion protection of the scratch. A challenge with hexavalent chromates is that they cannot endure temperature greater than 150°F without losing salt spray resistance.

### **Passivates / Trivalent Chromates**

Do not offer scratch resistance in most formulas but they do endure higher temperature (300°F) without loss of corrosion. Some will increase in corrosion when baked. Now a zinc plater who needs to zinc plate and apply a conversion finish can use a passivate without hexavalent chrome and go directly to baking with hydrogen embrittlement without having to apply the conversion finish after backing- saving money.

### **Sealer, Topcoats, and Lubricants**

Polymeric Seals – Acrylic, Urethane and Polyester Bases

Wax Seals

Inorganic Seals – Silicates, Silica

Pigmented Seals - Black

### **Mechanical Zinc**

Tumble part in concrete mixer with glass beads and chemicals – no hydrogen embrittlement.

### **Brass Plating**

Brass is an alloy of copper and zinc that can be found in many different colors.

Red-Brass is copper 80% by wt/zinc 20% by wt and is used mostly for a decorative finish. It is soft brass.

Yellow-Brass is copper 70% by wt/zinc 30% by wt and is the popular color for plumbing hardware. It is slightly harder than the red-brass. This color is the most popular for decorative finishes.

White-Brass is copper 60% by wt/zinc 40% by wt and was developed by Ford Motors as an application for plating on car bumpers. It was a substitute for nickel during the Korean War. It resulted in an excellent corrosion resistance finish without using straight nickel. It is a harder finish because it contains more zinc in the alloy.

Brass plating is mostly a decorative finish – bright flash over nickel and antique brass - with some functional applications. All brass plating baths have used cyanide as the completing agent. Unfortunately, cyanide is on the Department of Homeland Security list of a potential terrorist chemical of concern. A non cyanide brass has been attempted in the past, but there may be some opportunities with some limitations to the non cyanide brass solutions.

## **Black Oxide**

It is nothing more than black rust magnetite  $Fe_3O_4$ . Hot black oxide converts steel/iron  $Fe_2O_3$  into  $Fe_3O_4$ .

Hot black oxide is environmentally friendly in that it does not contain heavy metals. It contains the following:

- Sodium Hydroxide - Raise boiling point
- Oxides - Blackening
- Additives – Help in blackening

Black Oxide - Dimensions Stability - Almost dimensionless 5-10 millionths of an inch.

Purposes:

- Corrosion Protection
- Anti-Galling
- Reduce Glare
- Can Paint Over

Three types of Black Oxide:

- Conventional Hot Black Oxide - 285 . It is best for high quality blackening job shop situations.
- Mid Temperature – 180 - 210 . It does not do everything 285 blackening does.
- Room Temperature – Immersion deposit of copper and selenium.

The black oxide finish offers a small amount of salt spray (2 – 4 hrs per ASTM B-117) by itself. There are many types of corrosion inhibitors: water displacing oils, water soluble oils, waxes, and water base lacquers. These finishes offer 10- 400 hrs of corrosion per ASTM B-117.

## **Phosphate Coatings**

Phosphate coatings are typically three types of coatings: iron phosphates, used prior to painting and coating; zinc phosphates, used prior to painting and corrosion resistance; and manganese phosphate, used as an excellent lubricant/break in material plus good corrosion protection. This discussion is cover zinc and manganese phosphate.

### **Zinc Phosphate**

An inexpensive non-plated finish on steel that typically utilizes a rust preventive corrosion protection 48-250 hours to red rust. Zinc phosphate is typically heated for best results at 120-200 . The zinc phosphate coating is porous and absorbs the oil, increasing the corrosion protection. Zinc phosphate is measured by weight 300 – 600 mg /ft<sup>2</sup> microcrystalline and 1,200 – 3,000 mg/ft<sup>2</sup> for heavy zinc phosphate. A microcrystalline zinc phosphate is an extremely fine zinc phosphate that can be painted over. Typically, a zinc phosphate finish is a grey to black color. A black zinc phosphate can be achieved by using a black pre-dip, which is sealed by the zinc phosphate.

### Manganese Phosphate

A high temperature 180 – 210 °C phosphate that produces an excellent break in finish, for example on piston rings. The result color is black to grey depending on the alloy of the steel. Coating weights are 1,200 – 3,000 mg/ft<sup>2</sup>. The corrosion functions the same as zinc phosphate.

### Precious Metals

There are typically two different functions: one for electronics and the other is decorative. Gold, silver, platinum, rhodium, and palladium have all around various advantages, but at extremely high costs. Many precious metals are applied over other types of plates like copper and nickel.

Gold and its alloy have good electrical conductivity, and resist corrosion and formation of oxide films. Rhodium is used for when extreme hardness is necessary. Silver is used for its lubricity and its conductivity.

Obviously, precious metals are very expensive and its users find specific purposes in order to cost justify of the resulting finish.

### Decorative Chrome Plating

Nickel-chrome, or copper-nickel-chrome, is a finish you see on many of your Harley-Davidsons and aluminum wheels on cars. There also is hard chrome plating that is used for wear resistance. We will not discuss this chrome plating process.

Before decorative chrome plating became popular, people would nickel plate parts only. Eventually, the nickel plate would oxidize and change colors. It was discovered that a small plate of hexavalent chrome over the nickel results in a bright finish that will not tarnish, and thus nickel-chrome. Most steel parts you can plate nickel and chrome directly to the steel. Zinc and aluminum castings use copper thus copper-nickel-chrome. If you looking for specific information on a spec for copper-nickel-chrome, go to ASTM-B456. This specification will address copper-nickel-chrome plating on many various substrates, plating thickness, and service conditions.

The substrate for nickel-chrome plating is usually a plating grade with an excellent surface finish. Typically, the part is polished and/or burnished prior to being plated. Depending on the part, the first step is usually copper plating in cyanide or alkaline non cyanide copper. The next plate can be acid copper, which is known for its high leveling or bright nickel plating. The advantage of using acid copper is that it costs less than nickel and it is easy to buff, which will help fill in surface defects, thus saving some buffing and substrate costs.

The next step is nickel plating. You need to review the ASTM-B456 specification to determine if you use bright nickel only, semi-bright nickel/bright nickel, or semi-bright nickel/bright nickel/microporous nickel. There are also no or low sulfur deposits that help with corrosion protection.

The final step is plating hexavalent chromium or trivalent chromium plate on top of the nickel. Many corrosion tests are used. Salt spray and CASS (Copper Accelerated Acetic Acid Salt Spray) is a rapid test for chromium plated parts ASTM B-368.

### **Nickel Plating**

Nickel Plating is one of the most important metals applied by electrodeposition produces a high corrosion resistance finish. There are four main types of nickel plating processes:

- Watts Nickel (Bright Nickel) used prior to chrome.
- Sulfamate Nickel (Satin/Engineering) used for stress corrosion protection and hardness (Electroforming)
- Wood Nickel (Nickel on Stainless Steel)
- Electroless Nickel (High Corrosion Resistance Nickel) – no rectifier required

Refer to the ASTM-B456 specifications for nickel-chrome and copper-nickel-chrome.

### **Electroless Nickel (EN) Plating**

This is an immersion (auto-catalytic) chemical technique used to deposit a layer of nickel-phosphorous or nickel boron alloy on metals and plastics. No rectifier is necessary which results in an even deposit regardless of the shape of the part being plated, including blind holes. It is one of the most expensive processes to plate because it does not get its nickel metal from nickel anodes. There are three types of electroless nickel plating:

#### **Low Phosphorous**

1. Hard deposit
2. Very uniform thickness
3. Excellent corrosion resistance in alkaline environments

#### **Medium Phosphorous (1% – 5%)**

1. Very bright and semi-bright option
2. High speed deposit rate
3. Very stable (6%-10%)
4. Most commonly applied

#### **High Phosphorous (10%-13%)**

1. Superior corrosion resistance
2. Excellent acid resistance
3. Lower porosity
4. Non-magnetic
5. Less prone to staining
6. Pit-free deposits

I have talked about places where you can go like the ASTM for resources. Where else can you go? For a quick question, try [www.finishing.com](http://www.finishing.com). For educational resources, networking, trade show, government relations, and much more, go to [www.nasf.org](http://www.nasf.org) or National Association of Surface Finishers based in Washington D.C. The NASF is the consolidation of the AESF – American Electro Surface Finishing, NAMF – National Association of Metal Finishers, and the MFSA – Metal Finishing Suppliers Association. Together, these three organizations energy has been funneled into one organization that serves its members.

NASF is an international organization with local branches for its members that meet during the year. The next NASF Management Conference is February 27-March 3, 2011 in Phoenix, AZ at the Pointe Hilton Tapatio Cliffs Resort, and an annual trade show Sur/Fin, which will be held in Chicago, IL at Rosemont June 13-15, 2011. Sur/Fin is an excellent place to visit suppliers on the floor, learn about the latest new finishes, government regulations, network with your fellow finishers, and take educational courses like the Certified Electro Finisher (CEF) course.

The metal finishing industry is the second most regulated industry after the nuclear power industry. Therefore, we need the Washington D.C. Forum to be in constant communication with our Senators and Congressmen. In 2011, the Washington D.C. Forum will be held on April 12<sup>th</sup>-14<sup>th</sup> at the Ritz Carlton at Pentagon City. We also hear discussions from OSHA, EPA, REACH experts, Nickel, Energy and much more at this conference. Through our combined efforts, we have taken on the EPA's new limits on what is discharged in the air that would have closed the metal finishing industry for sure. One recent challenge was the OSHA chrome PEL was to be lowered from 52 to 0.5ppm. At 0.5ppm, there would be no more chrome plating in the US. It would cost too much for the equipment. The result was a higher limit on 5ppm of chrome that did not shut down the plating industry. Sorry for going off on a tangent here, but the EPA/OSHA regulations affect what you can choose for a finish based on regulation and cost.

Back to the NASF. There is now an excellent source for the engineer or requestor of finishes. NASF has revitalized its Metal Finishing Guide which is, or will be shortly, available online at [www.nasf.com](http://www.nasf.com). At this time, there are five Quality Metal Finishing (QMF) Guides on (1) Zinc and Zinc Alloy and Cadmium coating; (2) Decorative Copper-Nickel-Chrome; (3) Decorative Precious Metal Plating; (4) Electroless Nickel Plating and (5) Hard Chrome. Three more QMF's are on the way as we speak. The QMF's are the first step in learning more about metal finishing and how to specify a finish.

The NASF maintains three types of memberships: Individual Membership is \$150; Corporate Supplier (which is based on total sales) is \$1,100; and Finishing Shop (Job/Captive) which is also \$1,100. The NASF is the way to educate, network, and stay on top of the new regulations so that you can make the correct decision in your metal finishing process.