

Quality Metal Finishing Guide

Copper-Nickel-Chromium Coatings



1434 North Fourth Street, Milwaukee, WI 53212

P: 414-272-3433 • F: 414-272-0179

milwaukeeplating.com

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Howard M. Smith	M & T Harshaw
Donald L. Snyder	M & T Harshaw
Robert Tremmel	Enthone-OMI
Anthony J. Varuolo	MacDermid
Nabil Zaki	Frederick Gumm Chemical

quality metal finishing guide

DECORATIVE COPPER-NICKEL-CHROMIUM

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INTRODUCTION

The Metal Finishing Suppliers' Association (MFSA) is a trade association of companies and individuals engaged in providing the metal finishing industry with equipment, products, and supplies. A primary objective of the MFSA is to promote the interests and further the welfare of its members and their customers while safeguarding the interests of the ultimate customer. The MFSA, along with other groups in the industry, has long realized that the public, the industrial buyer, and the designers are many times not well informed about metal finishing of products nor how to specify quality coatings on industrial and consumer products.

In 1960 MFSA initiated action to upgrade the durability of metal finishes, in a program known as the "Quality Metal Finishing Project" or QMF. This project has been so successful that it is being continued and enlarged. It consists of programs aimed at:

- (1) promoting technically sound specifications and standards in cooperation with interested trade and technical societies;
- (2) providing information to both producers and buyers of metal finished products;
- (3) providing printed guides containing information on established standards and specifications, readily accessible for day to day use by the design engineer, the purchasing agent, and all those involved in the use of metal finished products.

There are now 5 Quality Metal Finishing Guides:

- (1) Decorative, Copper-Nickel-Chromium
- (2) Zinc and Cadmium Coatings
- (3) Mass Finishing
- (4) Tin and Tin Alloy Coatings
- (5) Electroless Nickel Plating

All of these Guides have been revised in the last one to three years.

The last several years have shown all industries the need for significant programs to maintain and improve quality in order to survive. Customers of the metal finishing industry have demanded quality improvements through organized efforts like the Ford Q-1 program, Malcolm Baldrige Award, etc. MFSA shares this recognition of the need to improve quality on an on-going basis.

As an association promoting the interest and welfare of the producers and customers of the metal finishing industry, MFSA realizes that all suffer loss when metal products are sold which are inadequately finished for the intended application. The consumer may be persuaded to shift to a non-metallic product. MFSA wishes to encourage the industry to build in the right amount and kind of high quality needed to assure the expected or promised service of the unit.

Industry needs to know how a high quality metal finish can be achieved, how to select proper specifications for a given application, and how to control the release of products to assure that they meet the needs of the customer. At the same time, management must be confident that this know-how is based on sound engineering principles and incorporates a reasonable margin of safety.

There have been significant developments of industrial standards for quality systems in the last few years which are applicable to metal finishing. These include the International Standard Organization (ISO) 9000 Standard and American National Standards

Institute/American Society for Quality Control (ANSI/ASQC) Q90 Standard. This manual will provide useful details on how to apply proven metal finishing engineering in your quality systems to help you maintain and improve your metal finishing quality.

DESIGN FOR PLATING

A program to improve and control the quality of a metal or plastic product should start at the desk of the designer. The metal finisher is restricted in what he can do by certain basic principles of mechanical finishing and of electroplating. The engineer should understand the limitations imposed by shape and size of components to facilitate quality finishing at an acceptable cost. The designer can exert as much influence on the quality attainable in finishing a part as can the electroplater himself. ASTM Standard B-507 can provide the designer with helpful information.

Significant Surfaces

A most important term used in specifying metal finishes is "significant surfaces" In most products the same standard of quality is not required over every square inch of surface. Instead, the quality specifications apply and compliance is expected only for the so-called "significant surfaces" defined by mutual agreement between the producer and purchaser as follows:

Significant surfaces are defined as those normally visible (directly or by reflection) which are essential to the appearance or serviceability of the article when assembled in normal position; or which can be the source of corrosion products that deface visible surfaces on the assembled article. When necessary, the significant surfaces shall be the subject of agreement between purchaser and manufacturer and shall be indicated on the drawings of the parts, or by the provision of suitably marked samples.

Design for Mechanical Finishing

Metal products which are to be coated with copper/nickel/chromium or nickel/chromium finishes are generally subjected to abrasive polishing with belts or wheels in preparation for the plating operations. This is done to aid in securing an attractive uniform, mirror-like or satin appearance on the finished part. Mechanical finishing is an expensive operation. To reduce costs and assist the metal finisher in improving the appearance and quality of the product the designer should consider certain rules applicable for parts requiring mechanical finishing.

- Avoid blind holes, recesses and joint crevices which can retain polishing compounds and metal debris.
- Avoid intricate surface patterns which will be blurred in polishing.
- Significant surfaces should be exterior, reachable by ordinary polishing wheels or belts.
- Avoid sharp edges and protrusions which cause excessive consumption of wheels or belts.

In small parts which are to be barrel processed the above rules apply plus a requirement that the parts must be sturdy enough to withstand the multiple impacts of barrel rotation. Small flat parts which tend to nest together should be provided with ridges or dimples to prevent this.

Design for Racking, Draining and Air Entrapment

Most metal or plastic parts weighing more than a few ounces are not plated in bulk in

barrels but are mounted on racks for processing in cleaning and electroplating tanks. Design considerations relating to racked parts are described in the following paragraphs.

Products which would occupy a large volume in processing tanks, large in proportion to surface area, should be designed to be plated in sections for assembly after coating.

Consult the plating department to make certain that parts can be held securely on a plating rack with good electrical contact without masking a significant surface. Many difficult racking problems can be solved by design modification.

Provide for good drainage of processing solutions from racked parts. Certain shapes tend to trap solution which then causes contamination by carry over, possible corrosion of the part and waste of materials. Carry over aggravates the problem of waste disposal. In design, avoid rolled edges, blind holes and spot-welded joints. Drain holes are especially important in irregular shapes and tubular parts.

Avoid shapes which can trap air on entry into processing tanks if this air could block access of solution to areas requiring treatment. Wherever air can be trapped, hydrogen or oxygen gas may also accumulate during a cleaning or plating step.

Design for Good Distribution of Electrodeposit

Experience and cost accounting show that simple shapes are always finished more uniformly and more economically than complex shapes. This is rule number one for the designer.

One of the most important factors determining the quality of a coating is its thickness on significant surfaces. Fundamental laws of electrochemistry operate to prevent a perfectly uniform deposition of an electrodeposited coating on a cathode of any practical shape and size. Portions of the work which are nearer the anodes tend to receive a heavier deposit. Sharp edges or protrusions at all current densities tend to steal a disproportionate share of the current. The goal of the designer and the plater is to make thickness variations as small as possible. At the same time, uneconomical wastage of metal by excessive build-up on both non-significant and significant areas must be avoided.

It is possible to estimate metal distribution ratios from models or mock-ups, but there are also empirical rules. These can guide the designer to improved uniformity of thickness, hence to improved quality with greater economy. These general principles and various sketches illustrate what has been learned from practical experience:

- Avoid concave or perfectly flat significant surfaces. Convex or crowned areas receive more uniform coatings. Use a 0.4 mm per 25.4 mm (0.015 inch per inch) crown—minimum.
- Edges should be rounded to a radius of at least 0.4 mm (1/64 inch) preferably 0.8 mm (1/32 inch).
- Re-entrant angles or corners should be filleted with a generous radius. Make such radii as large as possible.
- Avoid concave recesses, grooves, or slots with width less than one-half the depth.
- Minimize the number of blind holes because these must usually be exempted from minimum thickness requirements. Where necessary, limit their depth to 50% of their width. Avoid diameters less than 6 mm (7/32 inch).

- Countersink threaded holes to minimize electroplate thickness at their peripheries and facilitate insertion of fasteners after plating.
- If fins or ribs are required, reduce their height and specify a generous radius, 1.6 mm (1/16 inch) at each base. Round off tips with radii of at least 1.6 mm (1/16 inch). Multiple parallel fins should have spacing between centers equal to four times the width of the fin. Broad hollow ribs are preferred over slender solid ones.
- Adopt recessed in preference to raised letters and insignia, but round off edges and provide gentle contours.
- Integrated studs for fasteners should be shortened as much as possible and inside angles at each base should be rounded generously. Tips should be similarly rounded.
- Studs or bosses with hollow centers should be shortened as much as possible and angled 90 degrees from the major plane of the part. All bosses should face the same direction.
- Assist the plater by clearly marking significant surfaces in part drawings.
- Avoid use of a variety of basis metals in any one part to be plated. The contact of dissimilar metals may interfere by galvanic action with covering power or with adhesion of the deposit. Cleaning may also be complicated due to unequal reactions with the different metals.

DESIGN FEATURES THAT INFLUENCE ELECTROPLATABILITY

The effect of the basic design of a product or component upon the effectiveness or durability of the plating used has been the subject of much study and research. Many failures for which the plater has been blamed can be attributed to the original design.

A major contribution to the plating industry was made by the Zinc Institute, Inc. when it sponsored a design study by Battelle Memorial Institute which has resulted in the establishment of basic design principles to be applied to zinc die castings. The principles can be applied to other substrates.

The various shapes shown here provide the “do & don’ts” of design configurations and their relationship to electroplating quality.

Courtesy Zinc Institute, Inc.

INFLUENCE ON ELECTROPLATABILITY

Feature

The distribution of electroplate is indicated in an exaggerated fashion

Better Design

Convex surfaces



Ideal shape. Easy to plate uniformly, especially where edges are rounded.



Flat surfaces



Not as desirable as crowned surfaces. Use a 0.4mm/25.4mm (1/64 inch/inch) crown to hide undulations caused by uneven buffing.



Sharply angled edges



Undesirable. Reduced thickness at center areas and requires increased plating time for depositing a minimum thickness of durable electroplate. All edges should be rounded. (Edges that will contact painted surfaces should have a minimum radius of 0.8mm [1/32 inch]).



Flanges



Large flanges with sharp inside angles should be avoided to minimize plating costs. Use a generous radius on inside angles and taper the abutment.



Slots



Narrow, closely spaced slots and holes reduce electroplatability and cannot be properly plated with corrosion-protective nickel and chromium unless corners are rounded.



Blind holes



Must usually be exempted from minimum-thickness requirements. Where necessary limit depth to 50% of width. Avoid diameters less than 6mm (7/32 inch).



Sharply angled indentations



Increase plating time and costs for a specifically minimum thickness and reduce the durability of the plated part.



INFLUENCE ON ELECTROPLATABILITY

Feature

The distribution of electroplate is indicated in an exaggerated fashion

Better Design

Flat-bottom grooves



Inside and outside angles should be rounded generously to minimize costs.



V-shaped grooves



Deep, V-shaped grooves cannot be satisfactorily plated with corrosion-protective nickel and chromium and should be avoided. Shallow, rounded grooves are better



Fins



Increase plating time and costs for a specified minimum thickness and reduce the durability of the plated part.



Ribs



Narrow ribs with sharp angles usually reduce electroplatability; wide ribs with rounded edges impose no problem. Taper each rib from its center to both sides and round off edges. Increase spacing if possible.



Concave recesses



Electroplatability is dependent upon dimensions.



Deep scoops



Increase plating time and costs for a specified minimum thickness.



Spearlike juts



Buildup on jut will rob corners from their share of electroplate. Crown the base and round off all corners.



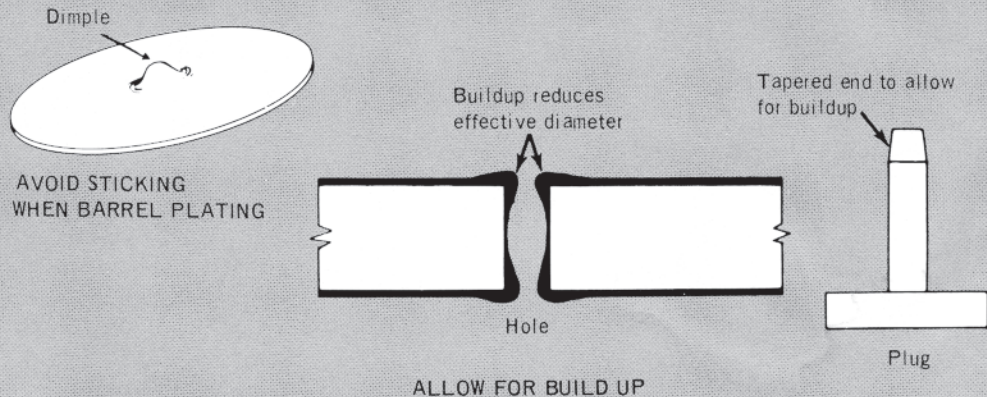
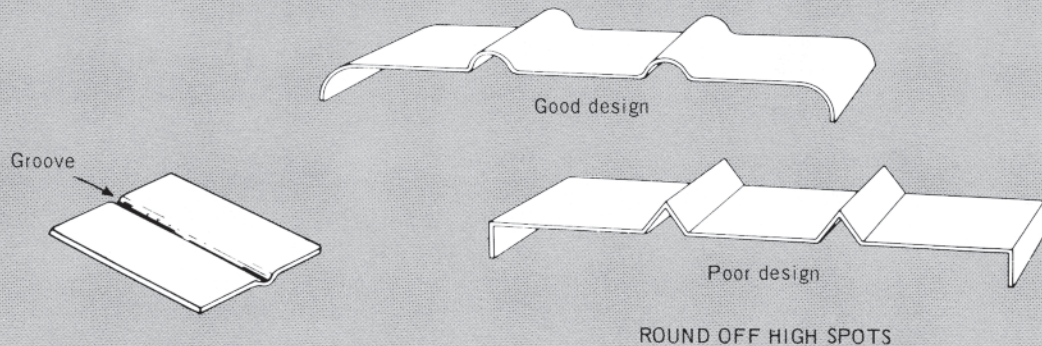
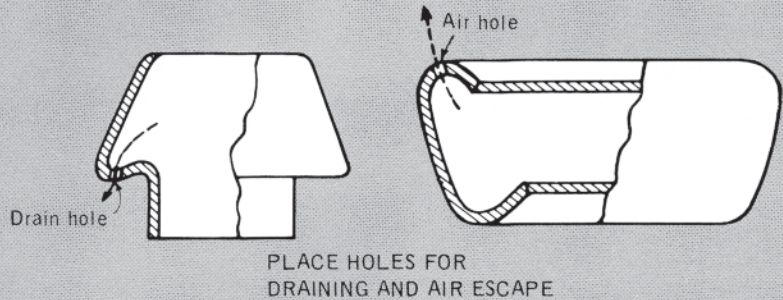
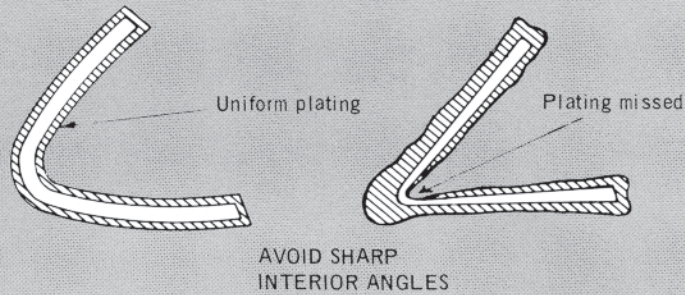
Rings



Electroplatability is dependent upon dimensions. Round off corners and crown from center line, sloping towards both sides.



DESIGN
FOR
PLATING



SELECTING THE FINISH

The designer should approach the problem of selecting the proper copper/nickel/chromium or nickel/chromium finish with a clear understanding of the requirements imposed on the plated product, the properties of the individual metals of the coating system and the service conditions to be satisfied. A properly selected decorative finish of high quality should be expected to perform acceptably throughout the service life of the product.

Requirements of the Finish

(a) Appearance

While appearance standards vary, the usual requirements are characterized by the deposits that have high reflectivity and are free of pits, clouds, and surface roughness. Such finishes are required in a variety of products including automotive parts, appliances, plumbing fixtures, bicycles, and tools. Chromium over suitable copper/nickel or nickel undercoats meets this need handsomely when high quality of the composite system is specified and achieved. Similarly, functional decorative applications e.g. flashlights, floodlights, electrical heaters, and instruments which require a high luster and mirror-like surface can be satisfied more economically by such finishes as compared to precious metal coatings. Satin and brushed surface effects can be produced as a more subdued finish. In contrast with bright or satin coatings, chromium and nickel can also be deposited as a non-reflective black oxide coating and lustrous surfaces for various applications can be obtained.

(b) Corrosion Behavior

To satisfy the prime requirement of maintaining an acceptable appearance, a decorative coating necessarily must effectively resist deterioration of itself and protect the basis metal from rusting or tarnishing in the broad family of paints, lacquers, sprayed metals and plastics as well as plated coatings. However, where a durable bright metallic finish is desired, the choice is limited. Chromium provides a top coating having excellent resistance to tarnish in atmospheric exposure and the copper/nickel or nickel undercoat provides the proper foundation for the lustrous chromium finish and the corrosion protection of the underlying steel, plastic, zinc, stainless steel, or other basis material.

(c) Wear and Abrasion

If the part must resist cleaning and handling or abrasive wear, copper/nickel/chromium or nickel/chromium finishes are usually specified in preference to softer metallic and organic coatings.

Coating Metals Considerations

(a) Rust Retardation

There are two classes of plated coatings which retard rusting or other corrosion of the basis metal. They do so by different mechanisms. The distinction arises from the different electro-chemical relationships between the coating and the basis metal when these are in contact with moisture. This can happen at a pore or other discontinuity in the coating. If the finish is anodic to the basis metal when exposed to a corrosive medium, then corrosion of the basis metal will be inhibited. This is the way in which zinc and cadmium and other anodic coatings retard the rusting of steel. The other class of finishes, represented by copper/nickel/chromium and nickel/chromium coatings are called cathodic

coatings. They show an opposite electrochemical behavior, since copper, nickel and chromium are generally cathodic to common basis metals. Such finishes actually tend to promote galvanic corrosion when only a few pores or cracks are present in the coating.

It is obvious that cathodic coatings must resist corrosive attack which could create pores or pits extending to the basis metal. From outdoor exposure tests it has long been known that a prime factor of quality of copper/nickel/chromium and nickel/chromium finishes is thickness. In general, the thicker the coating the longer the basis metal is protected. However, it was found that just increasing the nickel thickness up to two or three mils did not keep pace over the years with increasing severity of some outdoor urban environments. It was also not economical. Then it was discovered that multiple layers of nickel of differing composition give superior protection without increasing the total nickel thickness. These, together with modifications to the chromium plate, provided the means for a spectacular improvement in protective value while maintaining the appearance.

(b) Chromium

Chromium offers good corrosion resistance and abrasion resistance in the family of commonly plated metals. Thin chromium coatings over suitable undercoats provide excellent decorative systems. Furthermore, special chromium types can be deposited over copper/nickel or nickel undercoats so that the overall corrosion protective value of the system is increased.

Corrosion protection can be improved by the use of special types of chromium coatings. The useful life of the finish can be extended by the use of microporous or microcracked chromium. These invisible pores or cracks may be achieved by employing one of several existing process techniques. For hexavalent chromium processes, two methods are commonly used in North America to form microporous chromium. First method: a nickel strike containing micron sized inert particles are plated over the bright nickel and before the hexavalent chromium deposit. Pores are formed in the subsequent chromium deposit as it covers the inert particles. Second method: a spray of hard material such as sand or aluminum oxide is shot against the hexavalent chromium deposit just hard enough to microcrack the brittle chromium. In neither method is the appearance of the deposit affected. Microcracked chromium is essentially not used in North America. Chromium deposited from a trivalent bath is inherently microporous up to 0.6 microns, then it generally becomes macrocracked. Corrosion resistance is significantly increased by microdiscontinuous chromium. This improvement is particularly beneficial in such applications as automotive and marine hardware.

Chromium may be deposited from baths with the metal in either the hexavalent or trivalent state. The hexavalent or Cr^{+6} uses chromic acid as its source for metal, along with sulfates for control. There are proprietary catalysts used to improve efficiency and covering power. Hexavalent chromium has been identified as a carcinogen and several regulatory agencies have tightened its emission controls.

Trivalent chromium or Cr^{+3} processes use chromium sulfate or chloride as the source of metal. There are currently several processes available worldwide using this technology. One source uses special additives that prevent the oxidation of the trivalent chromium to hexavalent at the anode. Another process shields the anode with a cationic exchange membrane to prevent contact of the trivalent chromium with the anode.

Trivalent chromium technologies eliminated many of the deficiencies associated with hexavalent chromium plating such as high current density burns, white wash, poor throw, and high sensitivity to current interruptions. In addition, waste treatment is greatly simplified. Since trivalent chromium is not classified as a carcinogen, it is much safer and meets emission standards without the need for expensive emission control devices such as fume scrubbers.

(c) Nickel

The function of nickel is to provide a tough, durable, and ductile undercoat. Nickel protects the basis metal from corrosion and in combination with the chromium top coat results in a lasting decorative finish. Nickel levels micro-roughness in the basis metal, providing a smoother, brighter finish. With increased levelling in the nickel, the need for other expensive substrate preparation work is reduced.

In double-layer nickel undercoats for chromium finishes, the metal immediately under the chromium is bright nickel containing small amounts of sulfur (eg. more than 0.04 mass %) while the layer under that is semi-bright nickel essentially free of sulfur. In any galvanic electrolytic cell set up with the chromium, the bright nickel reacts anodically to the purer semi-bright nickel. If microscopic corrosion sets in through pores in the chromium layer and penetrates the bright nickel layer, galvanic action between the two kinds of nickel tends to cause the microscopic pit to spread laterally in the outer bright nickel layer. The net effect is to retard penetration toward the basis metal, hence, to lengthen the useful life of the coating. The negative effect is that as the lateral corrosion increases, the resulting surface pits may decrease the reflectivity of the corroded finish.

The potential difference between the semi and bright nickel layers can be measured by the S.T.E.P Test (ASTM B-764). S.T.E.P. potentials between 100 and 200 millivolts are typically specified. The higher the S.T.E.P. value, the more lateral corrosion occurs in the bright nickel layer before the semi-bright nickel layer is penetrated. This extends the time before basis metal corrosion but increases the rate of deterioration of the appearance.

The above galvanic corrosion system can be further enhanced by the use of three layers of nickel of different sulfur contents. In this case, a high potential nickel strike layer (high sulfur in the nickel) is deposited between the semi- and bright nickel. This strike acts as a sacrificial deposit to both these layers. Illustration 1. shows an excellent photomicrograph of this structure over copper plated steel. This further retards the corrosion penetration toward the basis metal while improving the appearance of the surface by minimizing the corrosion at the bright nickel/chromium interface. In general, when a high potential nickel strike is utilized, the potential of the bright nickel layer can be decreased to improve appearance after corrosion commences without a loss in basis metal corrosion protection.

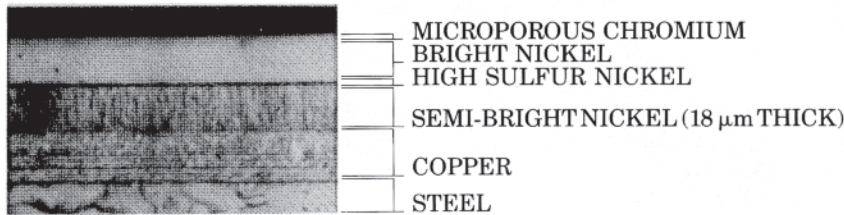
(d) Nickel-iron

Bright nickel-iron alloy coatings containing up to 50% iron are sometimes used as an economical substitute for single layer bright nickel deposits for mild or moderate service conditions. These coatings are generally more active than bright nickel coatings and consequently can provide improved substrate corrosion protection, compared to bright nickel, when used over copper or semi-bright nickel. The appearance of the more active nickel-iron deposit will deteriorate faster because of the larger surface pits which will form when corroded. Care must be exercised when choosing the alloy composition. An iron content exceeding 15-30% can result in significant surface staining (iron rust appearance) in moderate or severe service conditions. The exact level of iron in the deposit at which staining starts is subject to debate.

Nickel-iron coatings are generally more ductile than bright nickel deposits, are more easily replated, and cover better with chromium.

It is generally not recommended to use trivalent chromium or hexavalent chromium with high pore counts, (unless a pore sealant is also used), over nickel-iron alloy deposits due to the poor after corrosion appearance usually obtained.

**ILLUSTRATION 1.
PHOTOMICROGRAPH* OF COPPER/NICKEL
(3 LAYERS)/CHROMIUM PLATED STEEL**



*Courtesy of Enthone-OMI, Inc.

(e) Copper Undercoat

Nickel/chromium coatings may be deposited over a copper undercoat. ASTM specification B-456 has been established for copper/nickel/chromium coatings where microporous, microcracked, or conventional chromium is used. Alkaline copper coatings, generally cyanide, are first plated on zinc die castings to protect the active zinc from attack by the subsequent acid nickel processing.

As with nickel deposition, leveling copper processes can be used to upgrade the basis metal finish, and thus contribute to an overall improvement in the appearance of the final chromium finish. The excellent buffability of copper permits obtaining a high luster finish, and buffed copper coatings are employed when buffing costs can be justified. Ductile copper plate improves the apparent ductility of overlying nickel-chromium coatings. Bright leveling acid copper plate can minimize the undesirable effect of basis metal porosity by filling and bridging pores and also because of its superior micro-throwing power, will plate into sharp angles. Acid copper deposits are currently being used on some zinc die castings following a thin protective copper plate deposited from a cyanide bath.

In recent years, the development of a non-cyanide alkaline copper strike may allow the copper cyanide strike to sometimes be replaced; therefore permitting a copper strike and copper plating system to be used that is free of cyanides.

(f) Other Specialty Finishes

A number of modified finishes based on copper, nickel, or chromium can also be obtained.

- Antique and relieved copper plating

In this process, the copper plate is colored brown, black or green by immersion in sulfur based or other proprietary antiquing baths. The converted surface can then be relieved mechanically by light buffing or mass finishing then optionally sealed with a clear organic top coat. Examples of such applications are electrical fixtures, hardware, and clothing accessories.

- Decorative black nickel

In general, nickel is plated and then it is oxidized by either a dip or by electroplating of an alloy of nickel such as nickel-tin, nickel-zinc, and other available combinations. There are also proprietary black pure nickels that can be applied directly and which can be subsequently relieved. Typical applications of this process are luggage hardware, rivets, screws, etc.

- Black chromium

This is produced by using proprietary chromium plating formulations. The process and

equipment are similar to those for bright chromium plating. Solar collectors, furniture, and some camera components as well as other specialty decorative black finishes are plated by this process.

(g) Formability

Although basis metals with bright nickel/chromium finishes have been successfully drawn, stamped and otherwise formed, the bright nickel/chromium layer is relatively brittle. The best way to withstand forming operations is to plate the workpiece with a very ductile Watts or sulfamate nickel layer that is polished and/or buffed to obtain the desired finish and then plated with a thin micro-discontinuous chromium deposit. An alternative method that is less expensive and time consuming includes the use of micro-discontinuous chromium over the bright nickel coating. This tends to relieve the hydrogen embrittlement in the nickel layer, thereby improving formability.

The most economical and simplest method is to substitute decorative nickel-iron for bright nickel (Note the discussion on the properties of these deposits above). These coatings are more ductile, especially after chromium plating, which in some cases allows the plated parts to be formed or bent without having to resort to the use of special procedures or additional plating baths. This should only be done when the high corrosion protection offered by pure nickel is not required.

SPECIFYING THE FINISH

Having selected copper/nickel/chromium or nickel/chromium as the coating system for a steel, plastic, stainless steel, brass, zinc or other substrate, the designer must now specify the type, thickness and other characteristics desired in the coating. High quality can be obtained by properly specifying the types and thickness of layers to be applied. The designer must specify the appearance of the layer's finished surface. These will determine the protective value of the final part. The required performance tests such as adhesion and ductility should also be specified. For specific subjects, refer to the 1991 Annual Book of ASTM Standards, Volume 02.05, which covers Electrodeposited Coatings.

Type and Thickness

By type is meant the number and sequence of layers of copper, nickel and chromium which constitute the coating. A variety of multiple-layer decorative finishes have been developed by the various suppliers. Most are superior in protective value to a single layer of bright nickel covered by chromium. The large number of deposit types and combinations of layers can economically meet most performance specifications. See Tables I and II for recommended types and thicknesses meeting various service requirements.

Explanation of Tables I and II

(1) Service Conditions

Depending upon the customer, there are four or five service conditions which define the environment to which the plated part may be exposed as a function of the substrate.

(2) Classification

The classification letters shown in the tables indicate the type of deposit to be provided. The types of nickel are designated:

- b - for nickel deposited in the fully bright condition.

- p - for dull or semi-bright nickel requiring polishing/buffing to give full brightness, and containing less than 0.005 mass % sulfur (Note 0.005 mass % of sulfur is essentially a sulfur-free deposit).
- d - for a double-layer or triple-layer nickel coating of which the bottom layer contains less than 0.005 mass % sulfur and the top layer contains more than 0.04 mass % sulfur. The low sulfur layer should be from 60% to 75% of the total nickel thickness. If there are three layers, the intermediate one shall contain not less than 0.15 mass % sulfur and shall not exceed 10% of the total nickel thickness.

There is no restriction on the type of chromium used, except that one is not permitted to buff the chromium deposit. There are no restrictions on how the microporous and microcracked deposits are produced. The deposits must meet the following classifications:

- r - for regular (i.e., conventional) chromium. This deposit is non-microdiscontinuous hexavalent or trivalent chromium.
- mc - for microcracked chromium having more than 300 cracks per linear cm. (750/in.) in any direction over significant surfaces. The cracks shall be invisible to the unaided eye.
- mp - for microporous chromium containing a minimum of 10,000 pores per sq. cm. (65,000/sq.in.). The pores shall be invisible to the unaided eye.

**TABLE I
RECOMMENDED STANDARDS FOR QUALITY
NICKEL/CHROMIUM FINISHES ON STEEL,
IRON AND ZINC PRODUCTS**

Service Conditions	Classification		Minimum Thickness in micrometers		Typical Applications
	Ni	Cr	Nickel	Chromium	
SC 1 MILD Exposure indoors in normally warm, dry atmospheres; coating subject to minimum wear or abrasion.	b	r	10	0.1	Toaster bodies, rotisseries waffle makers, oven doors and liners, interior auto hardware, trim for major appliances, hair driers, fans, inexpensive utensils, coat & luggage racks, standing ash trays, interior trash receptacles, inexpensive light fixtures.
	p	r	10	0.1	
SC 2 MODERATE Exposure indoors in places where condensation of moisture may occur: for example, in kitchens & bathrooms.	b	r	20	0.3	Steel & Iron: stove tops oven liners, home, office and school furniture, bar stools, golf club shafts. Zinc Alloys: bathroom accessories, cabinet hardware
	p	r	20	0.3	
	b	mc	15	0.3	
	p	mc	15	0.3	
	b	mp	15	0.3	
SC 3 SEVERE Exposure which is likely to include occasional or frequent wetting by rain, dew or possibly strong cleaners and saline solutions.	p	mp	15	0.3	Patio, porch and lawn furniture, bicycles, scooters, wagons, hospital furniture, fixtures and cabinets.
	d	r	30	0.3	
	d	mc	25	0.3	
	d	mp	25	0.3	
	p	r	40	0.3	
	p	mc	30	0.3	
	p	mp	30	0.3	

TABLE I (continued)

SC 4 VERY SEVERE Service conditions which include likely damage from denting, scratching or abrasive wear in addition to corrosive media.	d	r	40	0.3	Minimum requirements for auto bumpers, grilles, hub caps and lower body trim. Light housings.
	d	mc	30	0.3	
	d	mp	30	0.3	
SC 5 EXTENDED—VERY SEVERE Service conditions which include likely damage from denting, scratching or abrasive wear in addition to exposure to corrosive environments where long-time protection of the substrate is required.	d	mc	35	0.3	Extended usage in exterior automotive and other items as in SC 4 above.
	d	mp	35	0.3	

Note: 5 micrometers copper is required on zinc and zinc alloys prior to nickel-chromium. 15 micrometers may be used on steel

25.4 micrometers = 1.0 mil

Adapted from ASTM Standard B-456

**TABLE II
RECOMMENDED STANDARDS FOR QUALITY
NICKEL/CHROMIUM FINISHES ON
COPPER AND COPPER ALLOYS**

Service Conditions	Classification		Minimum Thickness in micrometers		Typical Applications
	Ni	Cr	Nickel	Chromium	
SC 1 MILD Exposure indoors in normally warm, dry atmospheres with coating subject to minimum wear or abrasion.	b	r	5	0.1	Toaster bodies and similar appliances, oven doors and liners, interior auto hardware, trim for major appliances, receptacles, and light fixtures.
	p	r	5	0.1	
SC 2 MODERATE Exposure indoors in places where condensation of moisture may occur: for example, in kitchens & bathrooms.	b	r	15	0.3	Plumbing fixtures, bathroom accessories, hinges, light fixtures, flashlights, and spot lights.
	p	r	15	0.3	
	b	mc	10	0.3	
	p	mc	10	0.3	
	b	mp	10	0.3	
SC 3 SEVERE Exposure which is likely to include occasional or frequent wetting by rain or dew or possibly strong cleaners and saline solutions.	p	mp	10	0.3	Patio, porch and lawn furniture and light fixtures, bicycle parts, hospital and laboratory fixtures.
	d	r	25	0.3	
	d	mc	20	0.3	
	d	mp	20	0.3	
	p	r	25	0.3	
	p	mc	20	0.3	
	p	mp	20	0.3	
	b	r	30	0.3	
	b	mc	25	0.3	
	b	mp	25	0.3	
SC 4 VERY SEVERE Service conditions which include likely damage from denting, scratching or abrasive wear in addition to corrosive media.	d	r	30	0.3	Boat fittings, auto trim, hub caps, lower body trim.
	d	mc	25	0.3	
	d	mp	25	0.3	

(3) Use of Copper

Copper undercoats are preferred for deposits on plastic, zinc die castings and aluminum, where it protects the underlayers from acid solutions during subsequent acidic plating steps. Copper is sometimes specified for steel to improve the part's appearance and to cover up corrosion enhancing surface defects. Copper thicknesses are not substitutable for any part of the specified nickel thickness.

(4) Typical Application

The lists of a typical applications will help the designer or purchaser select a suitable coating specification if he is not certain of the service conditions to be met. In case of doubt as to the severity of a planned application, a classification should be specified suitable for the next more severe type of service condition.

Protective Value

The problem of specifying performance of decorative coatings involving copper/nickel/chromium and nickel/chromium composites has intrigued the metal finishing industry continually since the start of this century. The factors controlling corrosion are so numerous that the only valid test is exposure of parts to actual service conditions over the life of the part.

In recent years several accelerated corrosion tests have been developed which have shown some correlation with the performance of copper/nickel/chromium and nickel/chromium coated parts in moderate and severe outdoor urban and outdoor seacoast service. There is copious data available to support the specification of the number of hours of resistance to these accelerated corrosion tests, as shown in Table III, as a measure of minimum acceptable quality in coatings intended for a given type of service. The tests themselves are described under the heading "Testing the Finish".

**TABLE III
ACCELERATED TEST REQUIREMENTS
FOR COPPER/NICKEL/CHROMIUM COATINGS**

BASIS MATERIAL	SERVICE CONDITION	CORROSION TEST (Duration In-Hours)	
		CASS ¹	CORRODKOTE ²
Steel, Zinc Alloy, Copper or Copper Alloy	SC 1 Mild	—	—
	SC 2 Moderate	4	4
	SC 3 Severe	16	16
	SC 4 Very Severe	22	32 ³
	SC 5 Extended—Very Severe	44	—
Plastic ⁴	SC 1 Mild	—	—
	SC 2 Moderate	8	—
	SC 3 Severe	32 ³	—
	SC 4 Very Severe	48 ⁵	—

¹ASTM B-368

²ASTM B-380

³Two 16 hour Cycles

⁴ASTM B-604

⁵Three 16 hour Cycles

Cyclic corrosion tests involving cycles of heat, humidity, spray, etc. are beginning to be used in an attempt to better simulate natural environmental corrosion. The existing tests have not been standardized at this time, but individual companies do specify them.

The conventional salt spray test, ASTM B-117 which was instituted in 1914, has been generally discredited as an accelerated corrosion test for these decorative coatings largely because of lack of reproducibility of results and questionable correlation with service. It is recognized, however, that the test is still used in some segments of the plating industry because it can serve as an inspection tool to reveal gross defects in the coating and bare areas. It is mainly classified as a porosity test.

Adhesion

It can be specified that the coating shall be sufficiently adherent to the basis metal, and the separate layers of composite coatings shall be sufficiently adherent to each other, that the finished part will pass the adhesion tests described under the heading "Testing the Finish"

Appearance

Appearance cannot be readily specified because it involves factors such as brightness, roughness and uniformity of color which are not easily assessed objectively. Location and extent of surface defects may influence acceptability. It is suggested that samples be prepared which are acceptable to both manufacturer and purchaser as standards of quality in appearance.

Ductility

If the product is to be used in such a way that the coating will be formed or deformed in service it may be desirable to specify ductility requirements. If the coating contains semi-bright nickel, then ASTM Specification 456 calls out a minimum 8% elongation for that deposit.

TESTING THE FINISH

There are several methods for measuring the thickness of copper/nickel/chromium and nickel/chromium coatings, some being destructive of the part tested and others not. Most only measure a small area of the part and so thickness measurements are often made at several specified set-points or at different current density areas.

(1) Microscopical Method

The part under test is cut on a plane perpendicular to an area being measured and is mounted for metallographic examination. The cross-section is polished and etched to contrast the plated coating with the basis metal, (See Illustration 1. for a good example). The thickness is then measured with an optical microscope at a magnification great enough to permit measurements of thickness with an accuracy of plus or minus one micrometer (0.00004 inch) or one percent of the coating thickness, whichever is greater. Thicknesses below one micrometer are too thin for this method.

The method is obviously destructive, is time consuming and a high level of skill and experience is required by the operator. Despite these disadvantages, it is used to some extent for production testing. When there is disagreement in thickness measured by

other methods, the microscopical method is often selected as the referee test. This method has been accepted by ASTM as described in ASTM Standard B-487.

(2) Magnetic Methods

Since the magnetic properties of the basis metal and the various layers of copper/nickel/chromium finishes differ, it is possible to use these differences to determine the thickness of coatings. To use ASTM Standard B-499, the coating being measured must be non-magnetic and plated over a magnetic surface. Instruments are available that measure the force necessary to detach a small magnet from the surface of the finished part. Other instruments utilize the reluctance of a magnetic flux passing through the coating and basis metal to measure the thickness. Both are easy and rapid to operate. They are calibrated against standards of known thickness. The tests are non-destructive. Results are within 10 percent of the true thickness. These instruments cannot measure the thickness of nickel if there is an undercoat of copper present.

ASTM Method B-530 describes a magnetic test method for coatings on magnetic and nonmagnetic substrates. As described in these standards, only the appropriate method must be used for the deposits and substrate being tested.

(3) Coulometric Method

This method is also known as the electrochemical or anodic solution stripping methods. It depends upon measuring the number of ampere-minutes or coulombs required for a controlled anodic current to dissolve a coating from a small fixed area of the surface. The test is destructive. Instruments are available which record the current flow automatically so that they are simple and fast to operate. Coating thickness of chromium (greater than 0.0785 micrometers), and nickel and copper (between 0.75 and 50 micrometers) can generally be determined by these instruments. ASTM Standard B-504 provides some particulars on this method.

(4) S.T.E.P. Test

This method is useful to simultaneously determine both the thickness and electrochemical potential of individual nickel layers in multi-layer nickel deposits. The S.T.E.P. (Simultaneous Thickness and Electrochemical Potential) Test method is based upon the Coulometric Method and is destructive. As each nickel layer is stripped under a constant current, it requires a given voltage (electrochemical potential). This potential is determined by comparison to a standard electrode. The precision and accuracy of this method has not been independently determined.

The main function of this test is to monitor these variables on production parts. These measurements can also be used to indicate the corrosion protection offered by the overall system, ASTM Method B-764 describes this test in detail. Commercial equipment is available and requires minimal experience.

(5) X-Ray Spectrometry

By the use of X-Rays, this method measures the mass of the coating per unit area, which can also be expressed in units of linear thickness provided that the density of the coating is known. Equipment is available for this easy to operate, non-destructive method. Depending upon the instrument and the metals being measured, the accuracy decreases as the thickness increases. Known standards are used to calibrate the instrument. ASTM B-568 describes this method.

(6) Spot Test Method for Chromium

Like other chemical methods, the spot test for chromium thickness is destructive. A

circular spot on the surface is exposed to a drop of hydrochloric acid solution which attacks the chromium at a known rate. The time required for penetration through the chromium layer is a measure of the thickness. Precision of up to plus or minus 10 percent can be achieved. Details of the test method are given in ASTM Standard B-556.

(7) Weight Loss on Stripping

It is often possible to strip or dissolve a coating, chemically or anodically, without appreciable dissolution of the basis metal. By weighing the specimen before and after the stripping and estimating its surface area, the *average* thickness of the coating can be calculated. Sometimes, the entire sample, basis metal and coatings, is dissolved and the solution analyzed for nickel, chromium, copper and the ingredients of the basis metal. Again, the average thickness is what is obtained from the calculations. This method will not indicate significant surfaces with insufficient coating thicknesses. This method is often used in testing the quality of the finish on small barrel-plated parts. It is also used on other parts in which surface roughness, lack of accessibility, and other restricting factors make thickness measurements impractical by other methods.

Protective Value

The accelerated corrosion tests specified in Table III are a means of controlling the continuity and quality of copper/nickel/chromium coatings, but the duration of such tests does not have a good correlation with the service life of the finished article. Generally, the deterioration of the appearance of the deposits' surface is greater after these tests than typically observed in natural corrosive environments. Passing accelerated corrosion tests at the plating plant level helps to assure consistent quality parts. Details of the test methods are found in the corresponding ASTM Standards. The designer and purchasing agent need only know the general methods employed which can be briefly described as follows:

The CASS Test, ASTM Standard B-368, involves exposure to a fog of droplets of five percent sodium chloride solution containing enough acetic acid to maintain a pH in the acidic range of 3.1 to 3.3. The droplets also contain a small amount of cupric chloride to accelerate corrosion.

The CORRODKOTE test, ASTM Standard B-380, is conducted by applying a slurry of corrosive salts and kaolin to the significant surfaces of the specimen, allowing the slurry to dry, and then exposing the slurry-coated part to a highly humid atmosphere for a specified period of time.

After subjecting an article to the corrosion test for the specified time, it is examined for evidence of corrosion of the basis metal or blistering of the coating. It is up to the plater and the purchaser to determine which test to use and what constitutes failure after accelerated corrosion testing. These corrosion tests were developed to give a relative measurement of the protection of the basis metal and are not reliable for predicting surface appearance after use. The extent to which such surface alteration will be tolerated is again subject to agreement between purchaser and manufacturer.

Two other accelerated corrosion tests that are still found in the older literature but which are no longer considered useful are the NEUTRAL SALT SPRAY Test, ASTM B-117 and the ACETIC ACID-SALT SPRAY Test. The latter test had an ASTM number of B-287 but it was discontinued by ASTM in 1988. A general salt spray standard can be found in ASTM G-85.

Adhesion

There is no accepted quantitative standard test for adhesion. Qualitative tests are suggested in ASTM Standard B-571. A bend test involves repeated flexing or deformation of the plated parts until fracture occurs. Any separation of the layers or coating constitutes failure. In the file test a piece is cut out of the part with a saw, then a coarse file is applied to the cut edge of the coating so as to attempt to raise or separate it. There is also a quenching test in which the finished article is heated in an oven to an elevated temperature and then is quenched in cold water. If no test method is specified, pick the one that most closely simulates the possible adhesion failure mode for the part during actual service.

Ductility

ASTM provides two recommended practices for evaluating ductility. ASTM B-489 describes a procedure that consists of bending over a mandrel a narrow strip cut from a metal plated article. An elongation measurement is obtained from the smallest diameter mandrel that does not cause the deposit to fracture. When the shape is such that a suitable specimen cannot be cut from the plated part, a test panel may be prepared of appropriate basis metal or plastic, with the same coating system in the same baths.

ASTM B-490 is suitable only for evaluation of deposits having low ductility, such as nickel. It describes a procedure for measuring the ductility of electrodeposited foils obtained from the actual plating solutions. The recommended practice consists of measuring the bend of a foil held between the jaws of a micrometer; these are closed until fractures or cracks appear. This is the typical method used for decorative electroplated nickel deposits.

Microdiscontinuity

For enhanced corrosion protection with the same nickel thickness, microporous and microcracked chromium is used instead of standard, conventional, or "non-porous" chromium deposits. Several methods are available producing equivalent results. Microdiscontinuity is invisible to the unaided eye and so must be tested. ASTM B-456, Appendix X4 contains the most established method, the Dubpernell Test. This test enlarges the sites by plating copper only into the pores and cracks so that they can be visible under 100 to 200x magnification. A newer method used by the automotive industry corrodes the part for 22 or 44 hours in CASS, then strips off the chromium and observes, at low magnification, the surface pits created in the nickel layer through the microcracks or micropores of the chromium when exposed.

COPPER/NICKEL/CHROMIUM FINISHES ON OTHER SUBSTRATES

Aluminum Alloys

Aluminum usually requires special conditioning treatments to remove the natural oxides and alloying surface elements prior to plating. The most critical steps in plating on aluminum alloys are those relating to surface preparation.

A typical sequence consists of oil, grease, and buffing compound removal followed by removal of the surface oxide layer. The oxide layer is heavier and chemically more resistant on heat treated alloys. The choice of acid deoxidizers versus alkaline etchants

earlier in the cycle may depend on the extent of this oxide layer. Alkaline etching following degreasing is often used to remove extrusion or machining lines and other surface imperfections. Depending on the alloy composition, smut develops on the surface after etching. The choice of desmutter is based on the type of aluminum alloy processed. (Table IV)

Proprietary non-fuming and less hazardous desmutters are also available.

**TABLE IV
TYPICAL ALUMINUM DESMUTTING AND
ACID DEOXIDIZING SOLUTIONS**

FOR 1000 AND 2000 ALLOYS	
Nitric Acid	30-70% v/v
Water	Balance
FOR 2000 AND 4000 CASTINGS	
Nitric Acid	30-50% v/v
Fluoride	60-100 g/liter
Water	Balance
FOR 5000 ALLOYS CONTAINING MAGNESIUM (Mg) (MAY ALSO BE USED AS AN ALL-PURPOSE DESMUTTER)	
Nitric Acid	30-50% v/v
Sulfuric Acid	20-30% v/v
Fluoride	60-100 g/liter
Water	Balance
FOR OTHER COPPER OR MAGNESIUM ALLOYS (FLUORIDE MAY BE ADDED FOR SILICON CONTAINING ALLOYS)	
Sulfuric Acid	5-10% v/v
Hydrogen Peroxide	3-5% v/v
Water	Balance

A thin layer of oxide redevelops on the surface soon after desmutting and will affect adhesion when plated. This oxide must be replaced by thin metallic coatings applied by immersion. Single or double zincates and stannates are typical of such coatings.

Recent developments include modified alloy zincates which incorporate small amounts of nickel, iron, or copper in addition to zinc. These modified alloy zincates are more dilute and less viscous than conventional zincates. They produce fine, dense crystalline alloy zincate layers that typically improve adhesion of subsequent coatings.

A bronze strike is applied to a stannate treated surface. whereas either a copper strike, electroless nickel, or a sulfamate nickel strike is applied following zincate. After striking, normal electroplating procedures may be followed. SAE Standard J-207 specifies types and thicknesses of copper, nickel and chromium coatings on aluminum. ISO 1456 includes specifications for decorative nickel-chromium deposits on aluminum and aluminum alloys.

Although there are many fine proprietary processes on the market, some typical steps used on aluminum are given in Table V.

**TABLE V
ALUMINUM PREPARATORY SOLUTIONS**

Operation	Time Range (Minutes)	Temperature Range (°C)
A) Non etch clean	3-5	60-71 (140-160°F)
B) Precondition		
1) 50 vol % Nitric Acid (for commercial purity alloys) Rinse	1/4-1/2	21-24 (70-75°F)
2) 15 vol % Sulfuric Acid (for high magnesium content alloys) Rinse	2-3	82-88 (180-190°F)
3) 3:1 mixture concentrated Nitric and Hydrofluoric Acids (for high silicon content alloys) Rinse	1/3-1/2	21-24 (70-75°F)
C) Condition		
1) Stannate No rinse	1/6-1	24-29 (75-85°F)
2) Zincate Rinse	1/2-1	16-27 (60-80°F)
3) Phosphoric Acid Anodize Rinse (Time and temperature are varied for different alloys)	5-15	24-35 (75-95°F)

Plastics

Plastics and some other non-conductors can be finished by electroplating operations once the article is made conductive. The electroplate type can be selected as the user desires.

Among the plastic substrates which have been successfully electroplated in production are acrylonitrile butadiene styrene (ABS), polyphenylene oxide, polypropylene, polysulfone and nylon. The substrate most widely used today is ABS. The plastics mentioned all require different preparatory techniques.

The "preplate" operations prepare the plastic surface for electroplating. Virtually all the techniques involve the use of either electroless copper or electroless nickel to provide a conductive layer for subsequent electroplating. The techniques used are mostly proprietary and complicated enough to preclude discussion in detail here. However, some of the steps and usual operating conditions are shown on Table VI.

**TABLE VI
RECOMMENDED STEPS AND
OPERATING CONDITIONS TO PREPARE THE
PLASTIC SURFACE FOR ELECTROPLATING**

Operation	Time Range (Minutes)	Temperature Range (°C)
A) Clean		
1) Alkaline	1-5	43-60 (110-140°F)
2) Acid Rinse	1-3	54-65 (130-150°F)
B. Etch Rinse	1-10	60-71 (140-160°F)
C. Neutralize Rinse	1-5	21-60 (70-140°F)

TABLE VI (continued)

Operation	Time Range (Minutes)	Temperature Range (°C)
D. Catalyze Rinse	1-3	24-32 (75-90°F)
E. Accelerator Rinse	1-5	24-32 (75-90°F)
F. Electroless Plate		
1) Copper or	7-10	24-29 (75-85°F)
2) Nickel Rinse	5-10	24-35 (75-95°F)
G. To Nickel/Chromium Plating Operations		

The electroplated layers on metallized plastic substrates are essentially the same as plated on metal substrates. While plastic substrates do not corrode in the same manner as metal, the galvanic relationships of the electroplated layers in the coating is the same whether the substrate is metal or plastic. Therefore, when an article is exposed to corrosive atmospheres, the electroplate structure is selected to withstand corrosion penetration.

When plating plastics there is one layer that must be given special consideration; that is the copper electroplate. Copper plating serves two primary functions:

- 1) It effectively levels the etched, micro-roughened surface.
- 2) Its ductility serves as a cushion to absorb the temperature induced movement between the plastic and the coating.

Generally, 12 to 25 micrometers (0.0005 to 0.001 inch) of copper is deposited. The copper electroplating bath must provide a levelled and ductile deposit. ASTM Standard B-554 covers measurements of thickness of metallic coatings on non-metallic substrates.

Decorative applications for copper/nickel/chromium finishes on plastics include: Small appliance trim, automotive interior trim, automotive grilles and light bezels, plumbing faucet trim, knobs and shower heads, marine hardware, camera parts, candlestick holders, fashion trim on handbags and shoes and nameplates. ASTM Standard B-604 covers the specification for "Decorative Electroplated Coatings of Copper/Nickel/Chromium on Plastic" as does ASTM Standard B-727 for "Preparation of Plastic Materials for Electroplating".

Stainless Steel

Austenitic and ferritic stainless steels can be electroplated with decorative nickel and chromium to provide improved appearance and corrosion protection. Surface oils and buffing compounds are removed by hot alkaline soaks and electrocleaners similar to those used for mild steels. An anodically electrified acid is used to remove surface oxides and in conjunction with a Woods nickel strike provides acceptable adhesion. ASTM Standard B-571 describes typical adhesion tests that must be met.

The subsequent bright nickel layer is of sufficient thickness to provide the desired appearance. Microdiscontinuous chromium is required for severe service conditions to prevent the formation of large pits during corrosion.

Decorative applications for nickel/chromium finishes on stainless steels include: automotive window moldings, bumpers, light bezels, body side moldings as well as marine hardware and hospital supplies. The recommended process cycle for electroplating nickel and chromium over stainless steel is shown in Table VII.

**TABLE VII
RECOMMENDED PROCESS CYCLE FOR
NICKEL/CHROMIUM PLATING OF STAINLESS STEELS***

Operation	Time Range Minutes	Temperature Range °C
A) CLEANING		
1. Alkaline Soak	1-5	71-93 (160-200°F)
2. Alkaline Electroclean	1-2	66-82 (150-180°F)
3. Rinse		
B. ACTIVATION		
1. Electro-Acid (Anodic)	1-2	24-30 (76-86°F)
2. Rinse		
C. Nickel Plate		
1. Woods Nickel Strike	1-2	24-32 (76-90°F)
2. Bright Nickel	15-30	52-66 (125-150°F)
3. Microdiscontinuous Nickel Strike (Optional)**	1-2	52-66 (125-150°F)
4. Rinse		
D. Chromium Plate		
	1-2	32-50 (90-122°F)

*See ASTM Practice B-254 for more detail on preparation of Stainless Steel for electroplating

**Microdiscontinuous chromium is required for severe service condition since it allows slower and more uniform corrosion of the nickel layer.

Zinc Diecast

As mentioned in the preceding Coating Metals Consideration section, nickel/chromium may be deposited on zinc diecast when a copper undercoat is used.

The typical preparation steps to process zinc diecast parts are listed in TABLE VIII.

**TABLE VIII
RECOMMENDED PROCESS CYCLE FOR
NICKEL/CHROMIUM PLATING OF
ZINC DIECAST PARTS**

	Bath Concentration (oz/gal)	Time Range Minutes	Operating Temperature °C
A) Soak Clean	6-8	3-6	88-96 (190-205°F)
B) Soak Clean	4-6	2-3	49-54 (120-130°F)
Rinse			
C) Electroclean	6-8	1-2	49-54 (120-130°F)
Rinse			
D) Acid	4-5	1-2	about 22 (72°F) ambient
Rinse			
E) Copper Strike	Strike Formulation	2-3	as specified
Rinse			
F) Copper Plate	Proprietary Formulation	15-20	as specified
Rinse			
G) Activate (Optional) (Micro-Etch)	6-8	0.5-1	about 22 (72°F) ambient
Rinse			
(H) To Nickel/Chromium Plating			

GLOSSARY* OF METAL FINISHING TERMS

Activation	Elimination of a passive condition on a surface.
Addition Agent	A material added in small quantities to a solution to modify its characteristics. It is usually added to a plating solution for the purpose of modifying the character of a deposit
Adhesion	The attractive force that exists between an electrodeposit and its substrate that can be measured as the force required to separate the electrodeposit from the substrate.
Anode	The electrode in electrolysis at which negative ions are discharged, positive ions are formed, or other oxidizing reactions occur.
Anode Efficiency	Current efficiency of a specified anodic process.
Autocatalytic Plating	Deposition of a metal coating by a controlled chemical reduction, catalyzed by the metal or alloy being deposited.
Barrel Plating	Electroplating or cleaning of small parts in bulk in a rotating container (barrel).
Basis Metal (or Substrate)	Preceding metal or material upon which coatings are deposited (not necessarily the material the part is constructed from).
Blister	A dome-shaped imperfection or defect, resulting from loss of adhesion between a deposit and its substrate.
Bright Dip	A solution used to produce a bright surface on a metal.
Bright Plating	A process that produces an electrodeposit having a high degree of specular reflectance in the as-plated condition.
Bright Plating Range	The range of current densities within which a given plating solution produces a bright plate.
Bright Throwing Power	The measure of the ability of a plating solution or a specific set of plating conditions to deposit uniform bright electrodeposits upon an irregularly shaped cathode.
Brightener	An addition agent that leads to the formation of a bright plate, or that improves the brightness of the deposit.
Brush Plating	A method of plating in which the plating solution is applied with a pad, sponge or brush, within which is an anode and which is moved over the cathode to be plated.
Buffing	The smoothing of a surface by means of a rotating flexible wheel applied to the surface on which fine, abrasive particles are applied in liquid suspension, paste, or grease stick form.
Burnt Deposit	A rough, non-coherent or otherwise unsatisfactory deposit produced by the application of an excessive current density and usually containing oxides or other inclusions.
Bus (Bus Bar)	A rigid conducting section for carrying current to the anode and the cathode bars.
CASS Test	Copper Accelerated acetic acid Salt Spray (fog) testing. An accelerated corrosion test for some electrodeposits and for anodic coatings on aluminum. See ASTM Method B-368.
Cathode	The electrode in electrolysis at which positive ions are discharged, negative ions are formed, or other reducing reactions occur.
Cathode Efficiency	The current efficiency of a specified cathodic process.
Cleaning	The removal of grease or other foreign material from a surface. Alkaline Cleaning —cleaning by means of alkaline solutions. Anodic or Reverse Cleaning —electrolytic cleaning in which the work is the anode. Cathodic or Direct Cleaning —electrolytic cleaning in which the work is the cathode.

* Above definitions have been adapted from ASTM B-374, "Definitions of Terms Relating to Electroplating" and have been abbreviated where appropriate for this text.

	Diphase Cleaning —cleaning by means of solutions that contain a solvent layer and an aqueous layer. Cleaning is affected both by solvent and emulsifying action.
	Direct Current Cleaning —see Cathodic or Anodic Cleaning.
	Electrolytic Cleaning —alkaline cleaning in which a current is passed through the solution, the work being one of the electrodes.
	Emulsion Cleaning —cleaning by means of solutions containing organic solvents, water, and emulsifying agents.
	Immersion —see Soak Cleaning.
	Reverse Current Cleaning —see Anodic Cleaning.
	Soak Cleaning —cleaning by immersion without the use of current, usually in alkaline solution.
	Solvent Cleaning —cleaning by means of organic solvents.
	Spray Cleaning —cleaning by means of spraying.
	Ultrasonic Cleaning —cleaning by any chemical means aided by ultrasonic energy.
Coloring	(1) The production of desired colors on metal surfaces by chemical or electrochemical action. (2) Light buffing of polished metal surfaces for the purpose of producing a high luster, also called “color buffing”
Composite Plate	An electrodeposit consisting of two or more layers of metal deposited successively. For example, double or triple layer nickel.
Corrodkote Test	An accelerated corrosion test for electrodeposits. See ASTM Method B-380.
Corrosion	(1) Gradual dissolution or oxidation of a metal. (2) Dissolution of an anode metal by electrochemical action in a plating cell.
Covering Power	The ability of a plating solution under a specified set of plating conditions to deposit metal on the surfaces of recesses, deep holes, or low current density areas. (To be distinguished from Throwing Power.)
Crazing	A network of fine hairline cracks in a coating.
Critical Current	A current density above which a new and sometimes undesirable reaction occurs.
Current Density (cd)	Current per unit area.
Current Efficiency	The proportion, usually expressed as a percentage, of the current that is effective in carrying out a specified process in accordance with Faraday’s law.
Degreasing	The removal of grease and oils from a surface. Solvent Degreasing —degreasing by immersion in a liquid organic solvent. Vapor Degreasing —degreasing by solvent vapors condensing on the parts being cleaned.
Detergent	A surface-active agent that possesses the ability to clean soiled surfaces. They are classified by the charged ions and radicals they form when dissolved in water as Anionic (negatively charged), Cationic (positively charged), and Nonionic (electrically neutral) detergents.
Drag-In	The water or solution that adheres to the objects introduced into a processing tank.
Drag-Out	The water or solution that adheres to articles removed from a processing tank.
Ductility	The ability of a material to deform plastically without fracturing.
Dummy (or dummying cathode)	A cathode in a plating solution that is not to be made use of after plating. Often used for removal or decomposition of impurities.
Duplex Coating	See Composite Plate. This commonly refers to semi-bright nickel followed by bright nickel deposits.
Electroforming	The production or reproduction of articles by electrodeposition upon a mandrel or mold that is subsequently separated from the deposit.
Electroless Plating	A less accepted term for Autocatalytic Plating.

Electrolyte	(1) A conducting medium in which the flow of current is accompanied by movement of matter. Most often an aqueous solution of acids, bases, or salts, but includes many other media, such as fused salts, ionized gases, some solids, etc. (2) A substance that is capable of forming a conducting liquid medium when dissolved or melted.
Electrolysis	Production of chemical changes by the passage of current through an electrolyte.
Electroplating	The electrodeposition of an adherent metallic coating upon an electrode for the purpose of securing a surface with properties or dimensions different from those of the basis metal.
Electropolishing	The improvement in surface finish of a metal effected by making it anodic in an appropriate solution.
Etch	noun—A roughened surface produced by a chemical or electrochemical means. verb—to dissolve unevenly a part of a surface or metal.
Faraday	The number of coulombs (96,490) required for an electrochemical reaction involving one chemical equivalent.
Filter Aid	An inert, insoluble material, more or less finely divided, used as a filter medium or to assist in filtration by preventing excessive packing of the filter cake.
Flash (or Flash Plate)	A thin electrodeposit, less than 0.1 mil. See Strike.
Flocculate	To aggregate into larger particles, to increase in size to the point where precipitation is enhanced.
Hard Chromium	Chromium plate for engineering rather than decorative applications. Not necessarily harder than decorative chromium, but generally much thicker.
Hydrogen Embrittlement	Embrittlement of a metal or alloy caused by absorption of hydrogen typically during pickling, cleaning or electroplating.
Inert Anode	An anode that is insoluble in the electrolyte under the conditions prevailing in the electrolysis.
Mechanical Plating	The formation of an adherent metallic coating upon a basis metal by impingement of finely divided solid particles of the coating metal.
Metal Distribution Ratio	The ratio of the thicknesses of deposit upon two specified areas of a cathode. See Throwing Power.
Microinch	One millionth of an inch, 0.000001 in. = 0.001 mil.
Micrometer (Micron, μm)	One millionth of a meter, 0.001 millimeters. 25.4 micrometers = 1 mil.
Microthrowing Power	The ability of a plating solution at a specified set of plating conditions to deposit metal in pores or scratches.
Mil	One thousandth of an inch, 0.001 inch, which equals 25.4 microns (μm).
pH	The cologarithm (negative logarithm) of the hydrogen ion activity. A measure of an acidic (less than 7) or basic (more than 7) condition.
Passivity	The condition of a metal that retards its normal reaction in a specified environment and associated with the assumption of a potential more noble than its normal potential.
Peeling	The detachment or partial detachment of an electrodeposited coating from a basis metal or undercoat.
Pickle	An acid solution used to remove oxides or other compounds from the surface of a metal by chemical or electrochemical action.
Pit	A small depression or cavity produced in a metal surface during electrodeposition or by corrosion.
Plating Range	The current density over which a satisfactory electroplate can be deposited.
Polishing	The smoothing of a metal surface by means of the action of abrasive particles attached by adhesive to the surface of wheels or endless belts usually driven at a high speed.

Ripple (d-c)	Regular modulations in the d-c output wave of a rectifier unit, originating from the harmonics of the a-c input system.
Robber	See Thief
Sacrificial Protection	The form of corrosion protection wherein one metal corrodes in preference to another, thereby protecting the latter from corrosion (for example, zinc over steel).
Shelf Roughness	Roughness on the upward facing surfaces where undissolved solids have settled on parts during a plating operation.
Shield	noun—A nonconducting medium or panel for altering the current distribution on an anode or cathode. verb—To alter the normal current distribution in a plating cell (at the anode or cathode) by the interpositioning of a non-conductor.
Stray Current	Current through paths other than the intended circuit, such as through heating coils or the tank.
Strike	noun—A thin film of metal to be followed by other coatings. Or, the solution to produce this film. verb—To plate for a short time.
Substrate	See Basis Metal (or Material).
Tarnish	verb—Dulling, staining or discoloration of metals due to superficial corrosion. noun—The film so formed.
Thief	An auxiliary cathode so placed as to divert to itself some current from portions of the work which would otherwise receive too high a current density.
Throwing Power	The improvement of the coating (usually metal) distribution over the primary current distribution on an electrode (usually cathode) in a given solution, under specified conditions. The term may also be used for anodic processes for which the definition is analogous.
Water Break	The appearance of a discontinuous film of water on a surface signifying non-uniform wetting and usually associated with a surface contamination.
Work (Plating)	The material being plated or otherwise finished.

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SOURCES OF INFORMATION Societies and Associations

AMERICAN ELECTROPLATERS AND SURFACE FINISHERS SOCIETY (AESF)
 12644 Research Parkway
 Orlando, Florida 32826-3298
 (407) 281-6441 FAX (407) 281-6446

NATIONAL ASSOCIATION OF METAL FINISHERS (NAMF)
 401 N. Michigan Avenue
 Chicago, Illinois 60611-4267
 (312) 644-6610 FAX (312) 321-6869

AMERICAN SOCIETY OF ELECTROPLATED PLASTICS, INC. (ASEP)
 1133 14th Street N.W., Suite 1100
 Washington, D.C. 20005
 (202) 371-1323 FAX (202) 371-1090

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)
 400 Commonwealth Drive
 Warrendale, Pennsylvania 15096
 (412) 776-4841 FAX (412) 776-5760

AMERICAN SOCIETY FOR METALS (ASM)
 9639 Kinsman Road
 Materials Park, Ohio 44073
 (216) 338-5151 FAX (216) 338-4634

SOCIETY OF MANUFACTURING ENGINEERS (SME)
 One SME Drive
 Dearborn, Michigan 48121-0930
 (313) 271-1500 FAX (313) 271-2861

AMERICAN SOCIETY FOR QUALITY CONTROL (ASQC)
 611 East Wisconsin Avenue
 P.O. Box 3066
 Milwaukee, Wisconsin, 53202
 (414) 272-8575 FAX (414) 272-1734

NICKEL DEVELOPMENT INSTITUTE
 15 Toronto Street, Suite 402
 Toronto, Ontario M5C 2E3 Canada
 (416) 362-8850 FAX (416) 362-6346

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
 1916 Race Street
 Philadelphia, Pennsylvania 19103
 (215) 299-5400 FAX (215) 977-9679

BUMPER RECYCLING ASSOCIATION OF NORTH AMERICA (BRANA)
 216 Country Club Road
 South Glastonbury, Connecticut 06073-8266
 (203) 659-1762 FAX (203) 659-1762

METAL FINISHING SUPPLIERS' ASSOCIATION, INC. (MFSA)
 801 N. Cass Avenue
 Westmont, Illinois 60559
 (708) 887-0797 FAX (708) 887-1286

ELECTROCHEMICAL SOCIETY (ECS)
 10 S. Main Street
 Pennington, New Jersey 08534-2896
 (609) 737-1902

NATIONAL ASSOCIATION OF CORROSION ENGINEERS (NACE)
 Post Office Box 218340
 Houston, TX 77218-8340
 (713) 492-0535 FAX (713) 492-8254

CANADIAN ASSOCIATION OF METAL FINISHERS
 21 Bellehaven Crescent
 Scarborough, Ontario M1M 1H2 Canada
 (416) 261-7888 FAX (416) 261-4850